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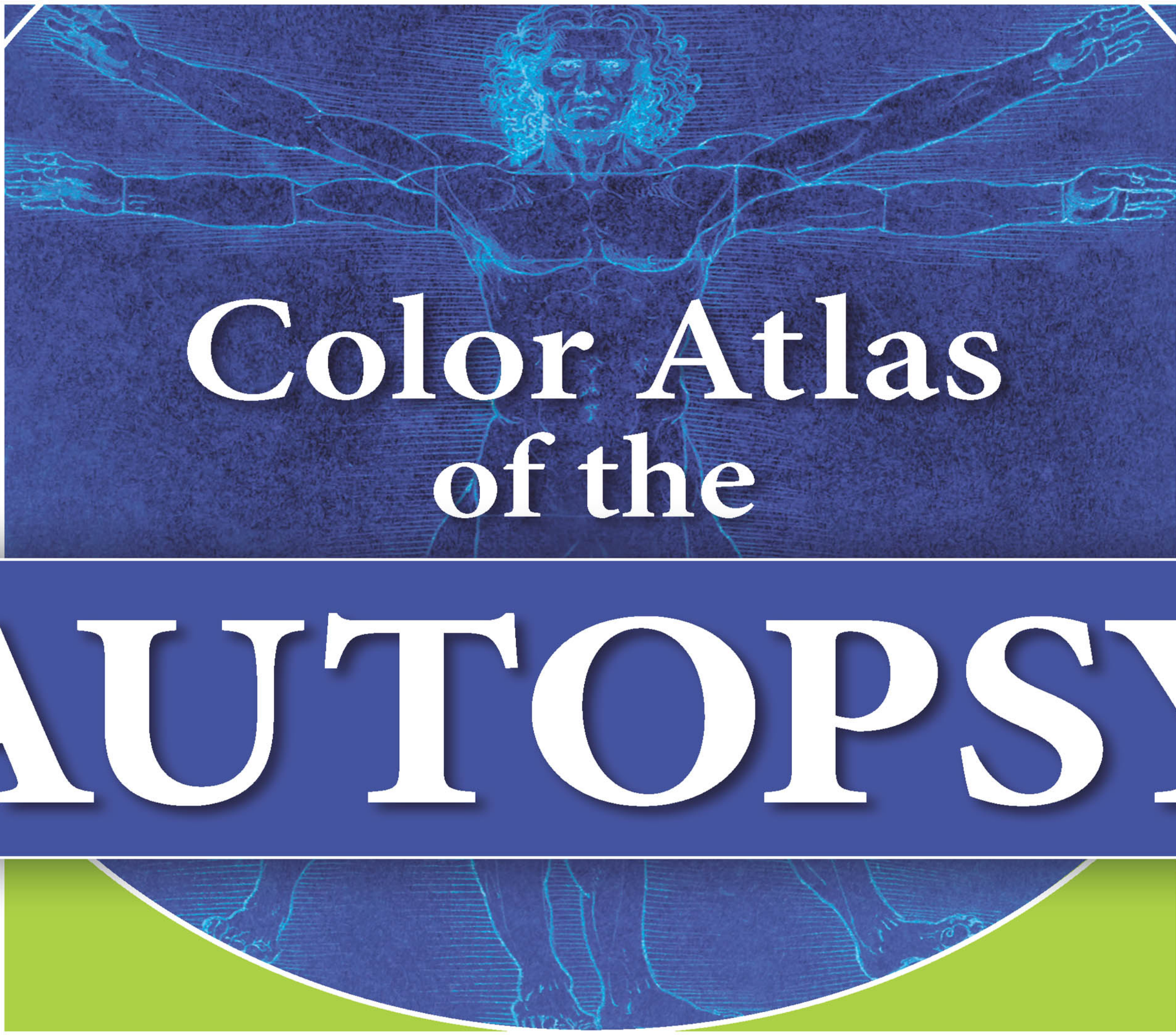

Color Atlas of the AUTOPSY

SCOTT A. WAGNER, M.D.

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PREFACE TO THE FIRST EDITION

Finally, there is a book that takes the reader through the autopsy procedure in a stepwise fashion, just as though the reader were at the autopsy. The chapters and the information in this book are revealed in layers, just like opening the body at autopsy. The aim is not only to show *what* is done in an autopsy, but *why* and *how* it is done. Many similar books have been written for pathologists or other physicians, but not for those who must work with pathologists. Death investigators, law enforcement officials, and other professionals need to know about the strange things pathologists do, as well as how and why they do them. This book is dedicated to and written for those patient souls who must interact with pathologists before, during, and after the autopsy.

The primary purpose of this book is to introduce the processes and principles of the autopsy procedure to the new and uninitiated. Because the autopsy is primarily a visual study of the diseases and injuries of the human body, images are essential to explain the process. Images are used in the book to tell the story of how the forensic pathologist develops opinions of the cause and manner of death.

This book is written as a natural extension of 15 years of teaching and demonstrating the autopsy to medical students, paramedics, flight nurses, nursing students, death investigators, law enforcement officials, firefighters, conservation officers, and other similar professionals and students of these professions. Many such professionals are involved with the practice of medicine and are eager to see the autopsy. For some, viewing an autopsy is an educational requirement. I have found it difficult to demonstrate an autopsy for all those professionals who need to see the procedure because the demand to see an autopsy exceeds the number of autopsies being performed. Also, the time for teaching during the 1.5-hour standard autopsy is limited. For me, it was difficult to orient the visitor to what I was doing. I finally realized that the professionals and students who came to my autopsy suite left with more questions than they had when they arrived.

I began looking for videos and other teaching aids to orient those uninitiated to the autopsy. I found that little or nothing was available, especially in the video medium. To fill this void, I produced the video *The Autopsy, Chapter One: Unraveling Life's Mysteries* in the year 2000. This video serves to teach and demonstrate visually the basic principles and practices of the autopsy. It allows the viewer to see three autopsies, with narrative explanations. Response to the video has been fantastic. Since its release, we have had numerous requests for written material to support and supplement the video medium. This book is largely a response to those requests. With narrative and over 500 still pictures, this book expands greatly on each aspect of the autopsy.

The reader should keep in mind that this is a basic book on the autopsy. The intent is not to teach one how to do an autopsy, but to show the processes and principles used in the basic forensic autopsy. Those who are interested in learning more details about anatomy, physiology, pathology, forensic pathology, and the other disciplines touched upon here should consult the suggested reading list at the back of the book. The methods demonstrated in this book are not meant to advocate only one way to perform the procedures. They simply indicate one way to do each procedure. The aim is to present a practical approach to the autopsy, with interesting findings presented along the way. One should think of this book as spending a few days at the author's autopsy table.

It is my intention that the information and images in this book be used only by professionals and students in fields related to law enforcement, death investigation, medicine, and law, or by funeral directors. Improper use of these images can be a violation of the law, and using these photographs in a salacious manner violates the basic ethics the author and his colleagues uphold. The first lesson to learn about the autopsy is reverence for the deceased and their families. It is in keeping with this reverence that I honor the deceased and use these images only to educate future and seasoned death investigators, detectives, nurses, paramedics, and other professionals. This is done to better our understanding of diseases and injuries, with the aim of benefiting the whole of humankind.

Scott A. Wagner

PREFACE TO THE SECOND EDITION

Now, 12 years after the first edition was published, there is even more interest and curiosity about the autopsy. However, with health records becoming more private, worries about infectious disease exposures, and the continual decline in the number of hospital autopsies, it has been increasingly difficult for most health care professionals to see an autopsy. This book serves to help fill that void by guiding the reader through the autopsy. As each page is turned, the reader looks deeper into the body.

With the success of the first edition of *Color Atlas of the Autopsy*, there came an interest in adding more pictures and descriptions of forensic injuries. *Color Atlas of the Autopsy, Second Edition* contains more extensive photos and text on many of the main forensic subject matters, including gunshot wounds, stab wounds, chopping injuries, and a new section on natural disease and forensic pathology. The reader is advised to start from page 1 in order to be guided through the reasons, theories, terminology, findings, and conclusions of the autopsy. The autopsy is about to start; get suited up!

ACKNOWLEDGMENTS

The author would like to thank the following:

My daughters, Amanda and Natalie; my colleagues, Bob Carpenter, M.D., Pamela Archuletta, M.D., and Shruti Shukla, M.D.; the creative assistance of Bethany Schwenn, D.D.S.; my staff of assistants, Bethany Wagner, Julianne Koval, Tiffany Hough, and Jason McCollough; and the professionals I work with, Mr. Michael Burris, Craig Nelson, D.D.S., Karen Richards, Esq., and Leslie Cook, R.N.

INTRODUCTION

The study of the autopsy begins with two basic assumptions: (1) the life of the individual is of the highest value; and (2) the deceased is to be treated with reverence. Our society holds the life of an individual above all else. If our culture had no reverence for life, we certainly would not care about death. Autopsies obviously do not benefit the dead; they benefit the living, and that is the focus of our study.

This book was written to fill a gap in the information about the autopsy. Books on the autopsy are normally written for physicians or experts in the fields of pathology and forensic pathology. While these books are essential for physicians and other experts in the field, no accessible books are available that show the process of the autopsy to those who interface with pathologists. It is often difficult for paramedics, crime scene investigators, firefighters, law enforcement officials, nurses, and students of these fields to observe an autopsy. Even when an autopsy can be viewed, the pathologist has limited time to explain the theories behind, and the purposes of, the autopsy procedure. Some professionals never see or experience an autopsy until they are on the job. Pathologists benefit when they interact with professionals who understand something about the autopsy—that is, what an autopsy can and cannot do.

This book is not a comprehensive study of the autopsy procedure. Anatomy, physiology, and histology are touched upon, but they are not the focus of the book. Forensic medicine and forensic pathology principles are introduced. However, the reader is advised to consult the bibliography for encyclopedic information on diseases and injuries. We depict routine autopsy procedures done in a convenient, practical way. There are many ways to approach and perform an autopsy, and we certainly do not mean to imply that our methods are the only ones, or even the best. Our aim is to expose the reader to the principles, common findings, and practices of the adult autopsy.

AUTHOR

Scott A. Wagner, M.D., is the director of the Northeast Indiana Forensic Center in Fort Wayne, Indiana, Principal at Forensic Pathology Consultants, LLC, and an Assistant Clinical Professor of Pathology at Indiana University School of Medicine. Dr. Wagner loves to share his fascination with pathology and forensic pathology with colleagues, students, coroners, nurses, law enforcement, first responders, and others. He has developed a video series, *The Autopsy, Chapter One: Unraveling Life's Mysteries*, and is also the author of *Death Scene Investigation, A Field Guide* (2009, CRC Press).

LIST OF VIDEOS

Video 2.1 Medical/circumstantial history: https://goo.gl/vChcBI. Knowing the circumstances of the death, and the medical history, if pertinent, are the cornerstones of a death investigation.

Video 3.1 External examination: https://goo.gl/rkd8va. The findings of the external exam, act as clues or guides for findings on the internal exam. In a forensic investigation, the external examination documentation and photography may take longer than the internal exam.

Video 3.2 Rigor mortis: https://goo.gl/UXAl4Q. The stage of rigor mortis is determined by examining the jaw, fingers, hands, arms, and legs.

Video 5.1 Skin exam and livor mortis: https://goo.gl/0f4BSB. The Skin acts as a sentinel for diseases or injuries inside the body. Livor Mortis is a discoloration of the skin by blood settling in the gravity dependent areas of the body, and is assessed during the external examination.

Video 6.1 Internal exam, opening the body and the Y incision: https://goo.gl/QzDYz7. The body is opened, looking constantly for bruising, fractures or other abnormalities.

Video 7.1 Opening the chest and collecting blood for toxicology: https://goo.gl/VKhlPZ. The chest is opened carefully, looking for air or fluid. Blood for toxicology is a cornerstone of the autopsy. Peripheral blood (femoral or brachial) is preferred as some drugs can concentrate in the centrally in the heart and great vessels after death (post mortem redistribution)

Video 7.2 Heart and lung excision: https://goo.gl/8x97Zo. The heart and lungs are carefully removed. Looking for emboli in particular.

Video 7.3 Abdominal assessment: https://goo.gl/Jqqqrz. The abdominal cavity must be inspected before the organs and bowel are removed.

Video 8.1 Examination of heart, lungs and liver: https://goo.gl/GnHqPY. These organs are examined as they are removed.

Video 8.2 Aorta examination: https://goo.gl/wGZ34e. The aorta can have atherosclerosis, aneurysms and dissections, and should be opened to look for these and other conditions.

Video 8.3 Neck examination: https://goo.gl/65uW6S. In forensic cases in particular, the strap muscles, hyoid bone, superior thyroid cartilage, and tongue should be examined for hemorrhage and injury to rule out strangulation and other conditions.

Video 8.4 Detailed examination of the heart: https://goo.gl/93qmkM. The heart is dissected in detail as the many deaths are cardiac in nature, chief among them being coronary artery atherosclerosis.

Video 8.5 Detailed examination of lung: https://goo.gl/f47Eeh. The lung is examined for the common conditions including pneumonia, tumors, and emboli, among many others.

Video 8.6 Detailed examination of liver: https://goo.gl/x5zAnq. The liver can display lacerations, which are often fatal. Common medical conditions include cirrhosis and metastatic tumors.

Video 9.1 Removal of the brain: https://goo.gl/V7pMPa. The brain is examined in every forensic case, as one can have direct observations of tumors, trauma, aneurysm, and stroke, among many other possible findings. If the brain is not examined, questions and speculation can be raised regarding the presence of trauma or disease contributing to the cause of death.

CHAPTER 1

APPROACH TO THE AUTOPSY: PURPOSE AND PHILOSOPHY

> To the living we owe respect, but to the dead we owe only the truth.
>
> **Voltaire**

WHAT IS AN AUTOPSY?

The autopsy answers the final question: why did life pass from the body of this individual? It is a question we have all asked when a loved one, friend, coworker, or even a public figure dies. The more untimely the death, the more tragic it seems, so many more questions arise. A wife asks why her healthy husband suddenly collapses, unresponsive. A young bricklayer cries out in pain and falls to his death from a great height as his coworkers look on in horror. An entire country wants to know how its president was assassinated. The autopsy serves to answer these and many other questions.

The autopsy is a complete evaluation of an individual's death and the circumstances surrounding that death. It includes a full examination of the body, and the autopsy has been called "the ultimate physical examination." This examination includes:

- A complete evaluation of the medical history and circumstances leading to the death
- The documentation of the position of and trace evidence on and around the body
- The photographing, description, and cataloging of injuries
- A detailed external examination of the body from head to toe
- An internal examination, including the dissection and examination of organs and tissues
- A microscopic examination of organs and tissues
- Laboratory and toxicological examinations of blood, body tissues, and fluids
- A written report detailing the pertinent findings, negative findings, and conclusions, including the cause and manner of death

A common misconception is to think of the autopsy as simply a dissection of organs. While the autopsy does involve dissecting organs, it is a much more comprehensive study of a person's death. The dissection portion of the autopsy is only a part of the complete examination that a pathologist performs. More than a simple medical procedure, the autopsy is a comprehensive consultation with the pathologist and part of a complete death investigation. Your family doctor takes the same approach. For example, you may go to your doctor because you are "tired all the time and want to find out why." You know your doctor will listen to your heart and lungs, but you want him or her to do more because your sluggishness might not be caused by a heart or lung problem. You want the doctor to use any means available to find out why you are so tired. He or she might have to perform blood tests or x-rays or take a detailed history from you. The pathologist approaches the autopsy in the same fashion, finding all of the medical or scientific facts, whether they lie in the medical history, dissection, examination of tissues, or toxicology results. The facts obtained in the autopsy are used to form opinions. The key opinions are usually the cause and manner of death, but can include important factors such as the time of death or injury patterns leading to finding the murder weapon.

The body of the decedent is treated with respect and dignity. The pathologist views the decedent as his or her patient, and accordingly treats the body as he or she would a family member. Except in rare and unusual circumstances, the autopsy does not alter any viewable portions of the body. Visitors to the funeral service cannot recognize that an autopsy has been performed, as the autopsy is much like a surgical procedure. A common misconception is that an autopsy can "mutilate" the body. On the contrary, this book will show how skillfully and precisely an autopsy is performed.

TYPES OF AUTOPSIES: HOSPITAL AND MEDICAL–LEGAL

There are two types of autopsies: hospital and medical–legal. Hospital autopsies are performed on inpatients of hospitals, upon the requests of families. Physicians cannot order these autopsies without permits signed by the highest-order next of kin. Autopsy permits often grant pathologists permission to study only those body parts that might help answer a specific medical question or

determine the mechanism of death. Most hospital autopsies are done in teaching hospitals, where the examinations are often quite detailed and are performed for institutional research and the education of medical residents.

Hospital autopsies are less common today than in the past for a number of reasons. The approximate $2500–$3000 cost is not covered by Medicare, The Affordable Care Act of 2010, or private insurers, so the expense is borne by the hospital or family. Hospital regulatory agencies no longer require autopsy quotas for accreditation, and more hospital deaths have come under the purview of the coroner and medical examiner systems. Previously, physicians eagerly sought autopsies to gauge the quality of medical care and to gain medical knowledge. In today's legal climate, some physicians fear that an autopsy might elicit facts that could be used in lawsuits against them. In the author's experience, the reverse is true—an autopsy generally demonstrates that the patient died of causes unrelated to the standard of medical care. Not performing an autopsy in this situation can lead to the worst assumptions (i.e., that poor medical care caused the death and that this substandard care is being covered up).

Medical–legal autopsies are performed at the behest of the medical examiner or coroner, who is required to investigate all suspicious and unnatural deaths (see the section "Unnatural Deaths"). In most states, a board-certified pathologist must perform these autopsies. The aim of medical–legal autopsies is to obtain the cause and manner of death (see the following bulleted lists). Because medical–legal autopsies are comprehensive examinations that include a study of the central nervous system, they exceed hospital autopsies in focus and scope. As medical science is increasingly able to prolong the lives of victims of severe trauma, more and more hospital deaths are coming under the jurisdiction of the coroner or medical examiner. Victims who, in past times, would have died at the scene or in the emergency room now either recover or succumb after a long hospital course. Since such traumatic deaths are considered a nonnatural manner of death, these cases fall under medical–legal jurisdiction.

The different aims of hospital and medical–legal autopsies are illustrated in the following example. A 92-year-old woman with significant cardiac disease falls down her steps and suffers a hip fracture. While convalescing in the hospital, she dies suddenly, 3 days after her accident and admission.

A hospital autopsy would focus on answering the following medical questions:

- Did she suffer a myocardial infarction or a pulmonary embolus (mechanism of death)?
- If her hospital care had been different (e.g., if anticoagulants had been given more aggressively), could her death have been prevented?
- If she was given a new anticoagulant under a research protocol, was this new drug effective? (This involves evaluating new drug protocols.)

The medical–legal investigation and autopsy would focus on the following:

- The injury (cause of death).
- The hip fracture. (Are the fall and subsequent fracture and the development of pulmonary emboli related?)
- How the injury occurred (manner of death): did she trip (accident) or did she have a myocardial infarction before falling down the steps (natural)? If she was pushed down the steps, the manner of death would be homicide.

If it was shown that this woman slipped and fell down the steps, sustained a hip fracture, and developed blood clots that embolized to the lung after 3 days of hospitalization, the death certificate would read as follows—"Cause of Death: pulmonary embolus due to fracture of the hip; Manner of Death: Accident."

When pathologists are asked to do an autopsy, they use any means available or known to them to answer the questions posed by the death investigation. A major part of this examination is the autopsy procedure itself. This book will show that the autopsy is a complex and comprehensive investigation into the causes and circumstances of death. The investigation of death and the autopsy can take the pathologist into virtually any field of medicine, engineering, science, law, law enforcement, and many other disciplines.

JURISDICTION AND PERMISSION FOR AN AUTOPSY

In medical–legal autopsies, the fundamental function of the autopsy is to establish the cause and manner of death. For medical examiner/coroner (MEC) offices, the autopsy is done in order to complete a death certificate and to register the vital statistics. A treating physician, coroner, medical examiner, or health officer can certify a death without an autopsy. Autopsies are costly; therefore, the jurisdictional authority or MEC office must be selective about choosing cases for autopsy. A coroner, medical examiner, judge, and, in some areas, a public health officer can order an autopsy without the permission of the next of kin. In most jurisdictions, if the next of kin desires an autopsy, this is given some weight in making the decision to request an autopsy. Due to budget concerns, the MEC office might not be able to accommodate all families that request an autopsy. The family can obtain a private autopsy by engaging a pathologist to perform the autopsy, usually at a fee.

Autopsies are usually not required when the patient has been under the regular treatment of a physician for a potentially terminal illness, and in such cases, the treating physician can certify the death. However, when a person dies suddenly, unexpectedly, or under suspicious circumstances,

even while under the treatment and care of a physician, an autopsy is usually required. Listed below are cases that nearly always require an autopsy. As one can see, virtually any death can come under medical–legal jurisdiction.

CASES THAT COMMONLY REQUIRE AN AUTOPSY IN MEDICAL–LEGAL JURISDICTIONS

- Homicides
- Suicides
- Any death due to a gunshot wound
- Accidents that occur on the job
- Drivers in single-car accidents (natural, accident, or suicide)
- Sudden, unexpected deaths of children
- Death of any child aged less than 14, unless two physicians can certify the death
- Deaths of pilots in aircraft crashes
- Natural diseases that might impact the community (e.g., meningitis)
- Fire deaths
- Accidental deaths potentially caused by the negligence or reckless behavior of others
- Deaths of persons in custody (or wards) of the state or other governmental agency
- Accidents that occur without a witness
- Accidents in which natural disease is a factor
- Sudden, unexpected deaths of apparently healthy persons (usually younger than approximately 75 years)
- Deaths in which the manner of death is not readily apparent
- Deaths in which litigation is reasonably expected
- Any hospital or medical facility death in which the quality of care is an issue
- Ostensible or very public deaths, even if the cause is likely known
- All suspicious deaths

Natural Deaths

When a disease, a syndrome, or a combination of diseases is the primary cause of death, the manner of death is categorized as natural. Investigating natural deaths is important to the coroner and medical examiner for at least two reasons. First, infectious diseases such as meningitis, human immunodeficiency virus, or hepatitis can be discovered, and those who had contact with the deceased can be evaluated and treated. Second, inherited diseases can be diagnosed, so living and future descendants of the deceased may be helped if they have correctable medical conditions. Families often express the need to know why their loved one died. In a society where medical information is private, largely because of the Health Care Information Privacy and Portability Act (HIPPA), certifying a natural death will make the major diseases and disorders of the person public. Coroners and medical examiners are mostly exempt from HIPPA when seeking health care information during a death investigation (The Health Insurance Portability and Privacy Act of 1996 [HIPPA; Pub. L. 104–191, 110 Stat.1936, enacted August 21, 1996]).

Natural is the most common manner of death. Even apparent accidental deaths can be proven natural after autopsy. For example, take a case where the driver of a vehicle suddenly swerves off the road and is found dead after only a minor crash. The autopsy shows a coronary thrombosis and subsequently a recent myocardial infarction. The infarction, or focal death of the cardiac muscle cells, causes a fatal cardiac arrhythmia and death. The death comes on suddenly and unexpectedly, so the man is unable to pull over before crashing. Finding a natural disease by autopsy in this situation is important for a number of reasons. First, the cause of the automobile crash is needed for accident reconstruction purposes. Second, life insurance policies often pay double indemnity if the manner of death is an accident. Third, alcohol and substance abuse are ruled out as causes of the crash. In the investigation of sudden, unexpected death, most individuals are also found to have died of natural causes, usually cardiac in nature.

Some classifications are done by convention, and appear inconsistent from the norm. For example, cirrhosis of the liver is classified as natural, even if the cause is chronic alcoholism and even though the person willingly drank alcohol and knew cirrhosis could result. This classification is done both by convention and presumably because the alcohol-induced cirrhosis developed over 10, 20, or more years. If a smoker with severe emphysema continues to smoke and dies from respiratory failure, this death would also be classified as natural. However, if a person willingly takes arsenic chronically, over years, then that death would be classified as a suicide.

Victims of homicides also have natural diseases. These diseases can accelerate death in some cases. In fact, an elderly man with severe heart disease might not survive the same gunshot wound that a young, healthy person would. Blood loss from a leg wound might be easily tolerated by a healthy 20-year-old, but an elderly man with cardiac disease might not survive the stress on his cardiovascular system and could develop a myocardial infarction. A fundamental principle in forensic pathology is "take the victim as you find him." In this example, we take the elderly man and the 20-year-old man as we find them, and the manner of death is homicide in both. We do not blame or hold the elderly victim accountable for his existing cardiovascular disease, even though the disease could have significantly hastened his death. The gunshot wound set into motion a chain of events that resulted in death. Even though the cardiac disease contributed to the death, the cause of death is the gunshot wound.

Unnatural Deaths

Autopsies are necessary in most unnatural deaths, including homicides, suicides, accidents, and those deaths in which the manner of death cannot be classified with the available information (often termed undetermined, unclassified, or "could not be determined"). Unnatural death is not a manner of death, *per se*. In an unnatural death, even though the cause and manner of death might appear obvious at the scene, an autopsy is usually performed. In an accident, finding the cause of the accident is essential, and an autopsy is often a large part of that investigation. In an apparent suicide, *intent* to kill oneself must be demonstrated and proven within reasonable scientific certainty. In a homicide, evidence must be collected and injuries must be documented. Autopsies are always performed in homicides or apparent homicides.

Homicides

A homicide is the killing of another human being, either by commission (e.g., shooting another person) or omission (e.g., neglect). Homicide is a medical term and opinion that is determined after a complete investigation and forensic autopsy. Murder, manslaughter, and reckless homicide are legal terms referring to the degree of action in the homicide. Certifying a case's manner of death as homicide does not mean that the perpetrator committed murder or will even face legal charges. For example, a perpetrator shooting a cashier victim at a store robbery is a homicide that is also a murder. If a policeman then interrupts the robbery and shoots and kills the perpetrator before he can kill other victims, this homicide is an example of a "police action" homicide. Police action homicides come under intense review by law enforcement and, ultimately, the local prosecutor or district attorney regarding the degree of action of the homicide (justifiable or not justifiable).

A common question is, "Why, in the case of a witnessed homicide involving a single gunshot wound of the head, is an autopsy necessary, when the cause of death is 'obvious?'" Here are but a few reasons for an autopsy in such a case:

- To confirm the cause and manner of death; that which appears as "obviously" true to a layperson occasionally proves to be false upon examination by an expert
- To provide photographic evidence for court proceedings
- To obtain the bullet and match it to a purported gun
- To track a bullet through the body (e.g., the bullet might not have entered the brain or skull, but examination of the neck may show that the person was strangled instead by a second perpetrator)
- To obtain trace evidence such as fibers and swabs for DNA
- To obtain independent confirmation of statements because witnesses might die or change statements
- To obtain specimens directly from blood vessels, the bladder, and other sites for toxicology tests
- To gather medical data for expert medical testimony
- To allow the forensic pathologist to explain direct observations, such as injuries, to the court and thereby act as a witness for the decedent
- To correlate the injuries and other observations on the body and the evidence with witness statements
- To generate a report for the defense and its experts to review
- Because the court and the jury expect that such an examination should take place (i.e., performing a complete autopsy in homicide cases is a legal and medical standard in the United States)

For the above reasons and more, it is the duty of the forensic pathologist to conduct a full medical–legal autopsy so that no reasonable investigative question remains unanswered. A thorough and complete job must be done even though the cause of death might seem "obvious."

Suicides

Suicide is the independent, willful taking of one's own life. Since ruling the manner of death as "suicide" must be proven beyond reasonable medical certainly, the suspicion of suicide usually requires an autopsy. The author has found that, when in doubt, a complete autopsy should be performed, especially in cases involving a firearm. One good reason for an autopsy is to rule out a possible homicide that has been made to look like a suicide. Although very unusual, it is possible that someone shot the decedent, produced a contact gunshot wound (see Figure 2.1), and simply placed the gun nearby. A gunshot wound suicide is always open to this allegation, and has been a theme in movies, television shows, and books. The unlikely possibility of a "homicide made to look like a suicide" can seem like a real explanation to friends and relatives, who may find the suicide of a loved one to be a devastatingly emotional event. These well-meaning people can cling to alternative theories to explain the death, such as homicide or an unusual accident. The religious implications of suicide are so powerful in some faiths that families might never agree with the ruling of suicide. Families and friends have been known to remove important evidence from the scene, presumably to prevent the conclusion that the death is a suicide.

The common theme in all suicides is the intent to kill oneself. Demonstrating this intent can be difficult. Friends and family may report previous suicide attempts. Scene investigation involves a search for evidence of this intent, such as a rope constructed for hanging, the wired trigger of a gun, the laying out of important personal documents, or a suicide note.

Accidents

Accidents also typically require autopsies. A fatal accident that happens on the job should receive a full investigation, including an autopsy. Deaths at the workplace come under the jurisdiction and are usually investigated by the Occupational Safety and Health Administration. Insurance companies might require an autopsy before

paying benefits. In the death of a law enforcement officer on duty, an autopsy is an absolute requirement for the investigation and for the family to receive certain death benefits. An accident involving alcohol or drugs has criminal implications and should receive a full investigation, including an autopsy. Accidents resulting from negligence should also be investigated.

Occasionally, accidents can appear to be suicides, such as in autoerotic asphyxia. In this accidental form of death, the victim uses a ligature around the neck to enhance sexual arousal. The ligature compresses the jugular veins, stopping venous return to the heart and cutting off oxygen to the brain. If the victim slips or becomes unconscious, death can ensue within minutes due to asphyxia.

Prescription drug abuse deaths (e.g., narcotics and benzodiazepines), acute alcohol toxicity, illegal drug overdoses (e.g., heroin), and combinations thereof are usually classified as manner of death, accident. In some situations, it can be difficult to determine whether the overdose was taken intentionally (suicide), accidentally, or if another individual administered the drug (homicide). In these cases, a complete death investigation, including an autopsy, is the best course of action to determine the true cause and manner of death.

THE AUTOPSY: ASSEMBLING A PUZZLE

The essence of the autopsy involves working backward from one undeniable fact: a death has occurred. Forensic pathologists look back in time to the point at which a disease or injury set into motion a chain of events that were ultimately, and tragically, fatal. A fundamental axiom in forensic pathology is "one takes the victim as one finds him." This simply means that the pathologist starts at the beginning of the death investigation, with a deceased victim, and makes no other assumptions. Facts are determined based on the examination of the specific victim, with his or her unique set of circumstances, medical conditions, and injuries.

Forensic pathologists do not work in a vacuum, however. While collecting information from various sources, they interact with crime scene investigators and law enforcement, review statements of witnesses, examine the scene, and follow leads that the scene provides. Analysis of this information sets the foundation for the autopsy procedure and the final opinions of the pathologist, including the cause and manner of death.

A comprehensive medical–legal autopsy has three phases:

- *Premorgue analysis* involves assessing the facts of the death scene (including environmental conditions), medical history, witness statements, and the known circumstances surrounding the death.
- *Morgue analysis* includes gathering trace evidence, external examination (including photographic and other documentation of the body), and internal examination of the body (commonly known as "the autopsy").
- *Postmorgue analysis* occurs over the ensuing weeks to months and includes analysis of microscopic slides of tissues sampled during the autopsy procedure. Toxicologic, microbiologic culture, chemical, and other laboratory results are also reviewed in this phase. Results of special forensic tests such as DNA identification, soil analysis, or insect identification are obtained from experts during this phase. Additional investigative information is often acquired during this time period.

The facts obtained from all three phases of analysis are assembled like the pieces of a puzzle to form a picture of the person just before death. The forensic pathologist views this picture of assembled facts in order to render an opinion, most importantly the cause and manner of death. The pertinent assembled facts and opinions are included in a written autopsy report. Occasionally, pieces of the puzzle are missing. In such cases, the forensic pathologist must use his or her experience and training to fill in the missing pieces and render an opinion.

Since an opinion is formed by the facts at hand, if the facts change, so can the opinion. For example, a gross autopsy in a case of sudden, unexpected death might initially show severe coronary disease. Days later, when the toxicology analysis is reported and high levels of multiple drugs are discovered, the cause of death must be changed to "multiple drug toxicity." Thus, the opinion given by the pathologist is based only on the facts known to him or her at the time that the opinion is given. If the facts are insufficient, the pathologist may have no opinion, and the cause of death will be ruled "no anatomic cause of death after complete autopsy and toxicological examination," and the manner of death will be ruled "undetermined."

WHAT IS A FORENSIC PATHOLOGIST?

In the United States, a forensic pathologist is a physician (M.D. or D.O.) who is board certified in pathology and forensic pathology. Board-certified pathologists have studied 4–5 years after medical school and have passed a board certification exam. Most forensic pathologists are board certified by the American Board of Pathology. Today, all forensic pathologists must take an additional fellowship year to study forensic pathology before sitting for the exam. For those of you who aspire toward a career in forensic pathology, that is 4 years of medical school, 4–5 years of residency, and an additional year of fellowship before you can begin the practice of forensic pathology.

A pathologist is a physician who specializes in the study of the laboratory diagnosis of diseases. For example, if your

aunt had a breast biopsy for cancer, the surgeon or radiologist will take the biopsy. That biopsy is processed to a very thin tissue slice that is placed on a glass slide. The diagnosis, be it benign fibrocystic changes or invasive ductal carcinoma, was made by a pathologist. If you had an abnormal complete blood count, a pathologist supervised that test and might have interpreted the result, reviewed a slide or smear of the blood, and reported findings to your family doctor.

Forensic pathologists work in several settings, including county, state, or the federal government in medical examiner jurisdictions. Medical examiners are often, but not always, forensic pathologists who are either appointed or elected to their positions. In some jurisdictions, coroners are legally compelled to perform the death investigations. Coroners are usually elected and may or may not be forensic pathologists, pathologists, or even physicians. The background and training of coroners across the country varies greatly. Nonpathologist coroners commonly include physicians, nurses, and funeral directors; they may have extensive backgrounds and experience, or no training or qualifications at all. The quality of these elected coroners, as with all elected officials, can vary from highly competent and experienced to inexperienced. In most states, these nonpathologist coroners must employ a pathologist to perform the autopsy portion of the death investigation. These pathologists are generally contracted to do the autopsy. This book will not explore the merits or problems with the death investigation system in the United States (see the references for sources on that topic). In any event, the majority of autopsies in the United States are performed by either a pathologist or a forensic pathologist. Some common duties of a forensic pathologist are as follows:

- Examination of a body at the scene of death
- Reviewing medical records for medical and forensic purposes
- Determining the cause or mechanism of injuries on both living and deceased persons
- Performing autopsies for the medical examiner or coroner system
- Acting as medical examiner or coroner
- Determining when other experts are needed (forensic odontology, forensic anthropology, etc.)
- Identifying trace and other evidence
- Testifying in court

Courtroom testimony is an important facet of forensic pathology. The pathologist who has performed an autopsy on a homicide victim will undoubtedly receive a subpoena to testify in court. In such cases, the forensic pathologist is an expert witness. An expert witness is very different from a fact witness. A fact witness, for example, testifies about what he or she observed and gives the date and time of this observation. Fact witnesses are not allowed to give opinions. Expert witnesses are allowed to give opinions to the court and to explain their answers. The pathologist must be qualified as an expert by the court. As an expert witness, a pathologist should be honest, speak loudly, and answer the questions that the attorneys ask. The pathologist should remember that the goal is to explain his or her opinion to the jury, not to take sides or try to help the prosecutor or the defense. All opinions given should be based on reasonable scientific certainty or reasonable medical certainty. The pathologist is, in a sense, the "witness for the truth," or a witness for the decedent.

CHAPTER 2

CIRCUMSTANTIAL AND MEDICAL HISTORY

IDENTIFY THE PROBLEM AND "CHIEF COMPLAINT"

Doctors are trained to focus on the major problems or "chief complaints" that patients present with when sick. A chief complaint is the main reason a patient visits a doctor, and the patient wants the "complaint" investigated and cured. Shortness of breath and chest pains are common chief complaints. To investigate a complaint, a physician takes the patient's medical history, performs a physical examination, orders or performs tests, and arrives at a final diagnosis. At this point, the chief complaint can be treated and the problem solved.

In medical–legal death investigations, forensic pathologists focus on specific problems in much the same way. For example, consider the case of a person found with a gunshot wound to the neck. The major problem or "chief complaint" raised by detectives is, "Does this case represent a homicide or suicide?" Initially, direct examination of the wound might suggest a contact gunshot wound (Figure 2.1), supporting the theory of suicide, because the markings on the wound indicate that the barrel of the gun was held right against the skin. Yet, before the cause and manner of death can be opined, the forensic pathologist must gather and integrate information from the scene, the detectives, and the other investigators (similar to a doctor taking a patient's medical history). In addition, a complete physical examination (autopsy) and laboratory testing (toxicology and microscopic slides) must be performed. The "doctor–patient" relationship has begun, as the decedent is the "patient" of the pathologist.

In order to address the complaint (diagnose the cause and manner of death), the pathologist must start by obtaining detailed facts about the circumstances surrounding the death. This information is known as the circumstantial history. The pathologist will talk to detectives to find out what witnesses, such as friends, family, or bystanders, saw or knew about the deceased and how he or she died. Detectives might discover that the deceased was under treatment for depression and had attempted suicide previously. The scene might reveal other facts consistent with a self-inflicted wound, such as the gun remaining in the hands of the decedent. A suicide note might be present. Soot and injuries from the gun mechanism might be on the hands and fingers (Figure 2.2). The pathologist uses this background information, history, and the examination of the body to render an opinion (final diagnosis) about the cause and manner of death. In this case, the history, scene investigation, and examination of the body allow the forensic pathologist to render the diagnosis—Cause of Death: gunshot wound; Manner of Death: suicide.

IDENTIFICATION OF THE BODY

Proper identification of the decedent is essential for many reasons. For one, the death certificate is a legal document that is required for burial and obtaining death benefits. In addition, since a death certificate is required to prosecute an offender in murder and related crimes, the identification must withstand a legal challenge. Correct identification is essential in homicide investigations, as incorrectly identifying homicide victims can bring undue anguish to the victims' loved ones.

The highest order of identification is scientific, including DNA and fingerprint analysis. Dental identification is highly reliable as well. These and other means of body identification are described below.

Direct Identification by Family Members

Direct identification of the body by family members, friends, or acquaintances is not always reliable. Uneasy relatives or friends might not take a good look at the body while in the morgue and may sheepishly agree to the identification. Family members simply may not recognize the body, as people look different when dead compared with the way they appeared when alive. The investigator commonly uses a photograph of the deceased to make identification and also notes if the individual was found in familiar surroundings, such as his or her house or car. Although viewing the face in the morgue is a common method of identification, pathologists find it much more effective to have a friend or family member view a photograph or video of the deceased's body. People tend to be more comfortable looking at a photograph in an office than at a body in the morgue. They are also less likely to take a cursory glance of the face and make an erroneous identification. This method of identification is not reliable when there are extensive injuries of the face such as charring from a fire, distortion of the face, or significant decomposition (Figure 2.3).

Personal Features

Personal features serve to back up the identification. The deceased might have deformities, scars, tattoos, or piercings. Unusual dental appliances can be useful as well (Figure 2.4). Hair length, color, and style; eye color; height; weight; clothing; and personal effects are commonly used to support the identification. Personal effects found in the pockets, for example, can help confirm identification (Figure 2.5a). Medical necklaces and bracelets can be helpful, as they also provide medical history (Figure 2.5b). Since tattoos are very common now, and are often uniquely combined, these serve as another reliable and practical way to make or support the identification (Figure 2.6).

Objects in the Body

Many people have metallic or other objects in their bodies that can be seen on radiographs. If comparison films are available, these objects can be useful in establishing identification. The more unique an object is, the more it facilitates a convincing identification. For example, sternal chest wires from open heart surgery can aid in helping establish identity, especially if the number of wires and their configuration match an individual's medical records and radiographs (Figure 2.7). Orthopedic rods or plates, particularly if the serial numbers on the rods are confirmed in the patient's medical record, can also be used to make a reasonable identification (Figures 2.8 and 2.9).

Higher-Order Identification

Higher-order identification is often needed when the deceased's appearance is altered in some way, such as from fire, decomposition, a mass-transit accident, and the like. Homicides commonly also require a higher-order identification.

Fingerprints

Fingerprints are commonly used for identification, but finger ridges might be decomposed or burned away due to charring. Fingerprint comparison is practical, inexpensive, widely available, and affords a rapid means of identification. Many of us have fingerprints on file somewhere; soldiers, veterans, law enforcement officials, gun permit holders, and those who have been arrested commonly have fingerprints on file. The Automated Federal Identification System (AFIS) is a nationwide computerized network that, by merging many databases, has made fingerprint identification easier and faster. The problem, of course, is that the unidentified individual's prints must be in the system. If needed, fingerprints can be lifted from known personal objects of the purported decedent, to the exclusion of other individuals who reasonably might have had contact with the personal item.

It is essential to obtain fingerprints in homicides for several reasons. First, the identification must stand up to a legal challenge (Figure 2.10a and 2.10b). In addition, especially if the deceased's prints are not on file, the known prints of the decedent must be compared to those found at the scene. The scene prints could be from the victim or from the perpetrator. Lastly, once the prints are in AFIS, they can potentially be used as a comparison in unsolved crimes. Failure to take the victim's prints leaves at least two unknowns: the victim and at least one perpetrator.

Dental Identification

Dental identification is another relatively rapid means of identification if ridged skin on the fingers is gone or if the person does not have prints on file. The investigator must search for any dental records of the purported decedent. This is sometimes difficult, especially if the decedent had not seen a dentist in a while (or ever). In addition, teeth might have fallen out over time or might have been extracted. Postmortem x-rays (Figure 2.11) or findings from direct examination of the teeth are compared with dental films (Figure 2.12) or other records (Figure 2.13) of the deceased that were created during his or her lifetime. These comparisons are made by a forensic odontologist, a dentist specializing in making identifications for medical–legal purposes. This method of identification is usually rapid and very practical if dental records and a forensic odontologist are available.

DNA

DNA is a unique molecular fingerprint that can identify an individual with a certainty estimated at one in the billions. DNA is a powerful tool if used correctly and proper procedure is followed. The sample must be collected so that there is no question of contamination. In decomposed bodies, bone marrow from teeth, ribs, or vertebrae often, but not always, yields useable DNA. There must be other DNA to compare it with, either from the deceased, a sibling, a child, or another relative. DNA or fingerprints from the deceased can be obtained from personal items, such as a hairbrush.

Since DNA analysis became available in the mid-1980s, it has revolutionized identification procedures and criminal justice. Positive blood type analysis in the past could only be given in terms of a certain percentage of the population. Currently, a positive DNA sample can statistically narrow down the identity of an individual to one in billions to a trillion. DNA analysis is not the answer for identifying all individuals and solving all crimes. The public may expect every crime and even every death investigation to include some sort of DNA analysis. Due to the expense, time, and the need for samples from parents or other relatives, DNA is only used for identity in those cases in which other forms of identification are not adequate.

Each person has a unique (unless there is an identical twin) collection of DNA within the nuclei of all their cells. Mitochondrial DNA is the exception. Mitochondria are small organelles found in all cells, containing a small amount of DNA that is different from the large amounts found in the nuclei of cells. Mitochondrial DNA is passed *unchanged* from the mother to all of her children. DNA is a long molecule with many sequences containing only four

amino acids. In DNA analysis, the DNA is extracted from the sample, and then short sequences of DNA (short tandem repeats [STRs]) are replicated into many copies. These copies of short DNA sequences are then measured, producing a *profile*. The profile of the unknown person or *evidence sample* is compared to the standard sample.

When all of the DNA sequences (DNA profiles) are identical, the results are reported as a "match." The result is also given weight in terms of how probable or how frequent a given DNA profile is found in a given population. This probability calculation gives the investigator or jury an idea of how much weight to assign to a given result.

Polymerase chain reaction and the newer STR methods are much quicker and require less DNA than the older restriction fragment length polymorphism testing. The STR method is superior to the other methods because the fragments are small and easily amplified so that analysis can be performed on a very small amount of DNA or with degraded samples. In 1998, the FBI set up the Combined DNA Index System, a database for the DNA profiling of individuals based on 13 different STR loci. Mitochondrial DNA is used as a last resort when the DNA is severely degraded. Mitochondrial DNA is more robust, and there are more copies in the cell than nuclear DNA.

Samples of blood can be stored indefinitely on commercially available cards, so that the DNA can be analyzed if any future questions arise regarding identity, criminal involvement, or paternity.

Investigative Questions

The investigation of death begins a process of answering key pertinent questions. These are questions asked by the state, courts, law enforcement, doctors, families, society, and many others. Questions that are not answered in the initial investigation might be answered by the autopsy. The autopsy, or evidence collected at the autopsy, usually spurs further investigation. Some questions are easily answered, some are difficult to answer, and at times some go unanswered.

Basic Demographic Questions

The following demographic information is collected:

- Full name of decedent, including at least the middle initial.
- Maiden name (if applicable).
- Sex, race, age, and date of birth.
- Social Security and driver's license numbers.
- Address of residence, including city, state, and zip code.
- Marital status—single (never married), married, divorced, or widowed.
- Home/mobile phone number. Facebook pages and the like are often useful to search.
- Next-of-kin contact—relationship to deceased, name, address, and telephone number.
- Date, location, and time of notification of next-of-kin and by whom.
- Employment history—position, name, address, telephone number of company, supervisor's name, and current status (retired, employed, "laid off"?).
- Preliminary identification—how and when made, and by whom.

Occupation

It is important to know the occupation of the decedent, particularly in accidental deaths; for example, if an apparently electrocuted man was a certified electrician or a weekend repairman (Figure 2.14). Deaths at the workplace are investigated by the Occupational Safety and Health Administration, so it is helpful to understand the decedent's training and duties at the workplace. Veterans will have military records and may have Veterans Administration records. Many occupations are hazardous by nature, and also may be associated with occupational diseases. Farmers, for example, perform many dangerous tasks and can become victims of anything from tractor rollovers to falling into a grain silo.

Obtaining a Medical History or Information

Since approximately half of the deaths that fall under the jurisdiction of the medical examiner or coroner are "natural" in terms of manner of death, the death investigator spends a great deal of time obtaining medical records and information. Medical information is obtained from many sources, so the death investigator must play the role of "medical detective" and investigate the many available clues and bring this information to the autopsy. The autopsy might reveal an unknown condition that prompts further investigation into the medical history of the decedent and family. For example, the author once found an aortic aneurysm in a 14-year-old girl who died suddenly while running. Knowing this condition to be genetic, a study of 12 family members showed the same abnormality in three of them, thus saving those individuals from the same fate as their relative.

The medical history can also have a bearing on other manners of death. The cause of a car crash can be the result of a natural disease, such as an epileptic seizure or a diabetic with hypoglycemia (low blood sugar), and therefore not due to driver error. A suicide might be explained by finding out that a person had recently been diagnosed with advanced cancer (Figure 2.15). Even in a homicide, a medical history can have an important bearing on the case, such as in cases of neglect of a dependent leading to fatal diseases, as seen in sepsis due to open, neglected bed sores.

Obtaining Medical Information at the Death Scene

Medical information is obtained at the death scene by searching for information and interviewing the family, friends, neighbors, and other people present at the scene.

This search may be as simple as finding an inhaler for asthma near to a decedent who was having "breathing problems" or as complicated as going through cabinets full of medication at a residence. Individuals who might have knowledge of the decedent's medical conditions or complaints must be interviewed. These interviews and searches often prompt the obtaining of medical records from doctor's offices, hospitals, and clinics. Since many people do not take what the doctor ordered and often reject advice given at the hospital, interviewing the witnesses and searching the scene reveals a more complete picture of the medical condition of the decedent.

Potential sources of information regarding medical history at the scene include the following:

- Interviewing family, friends, or neighbors
- Searching the house for medications and other medical devices (e.g., oxygen)
- Searching for medical bills and actual medical records
- Looking at an address book, computer, smartphone, or documents at home for names of doctors, clinics, hospitals, and pharmacies
- Searching the wallet, purse, and pockets for device cards, medication lists, and appointment cards

Medications

Medications are often the key to finding the cause of death. Many diseases or conditions can be lethal when the patient stops taking medication. Epilepsy, diabetes mellitus, and unstable angina are common conditions that can become quickly fatal if one does not take medication properly. Conversely, medication overdoses (accidental, accidental due to recreational use, or intentional) are also common causes of death. At the beginning of the investigation, it is helpful to obtain all medication vials, check the dates that prescriptions were filled, and then determine if the number of pills missing matches the prescription instructions. Finding heart failure medication, an inhaler, insulin, antibiotics, and home oxygen indicates that the patient had heart failure, severe chronic lung disease with an infection, and diabetes. In addition, the treating physician and likely the hospital information can be obtained from the bottles (Figure 2.15). Prescription drug abuse in the United States has risen to an epidemic level. This problem involves the illegal and recreational use of another person's prescription medication, whether by purchasing it illegally or stealing it, or simply taking it from the others person's supply. Common popular drugs include narcotics such as oxycodone and fentanyl and benzodiazepines such as diazepam or alprazolam. When taken together or when taken with other commonly used drugs such as cocaine, heroin, methamphetamine, and alcohol, a deadly combination is formed, causing central nervous system depression, coma, and cardiorespiratory arrest. When investigating these cases, there is usually a history of drug abuse. In the author's experience, one has a difficult time finding the offending medications or trappings of drug abuse at the scene, as they may be removed by friends, family, or associates upon finding the body (Figures 2.16 and 2.17).

Medical Records

Medical records can be obtained by calling or visiting a hospital, health care facility, or doctor's office. The Health Insurance Portability and Privacy Act (HIPPA) regulations state that law enforcement, coroners, and medical examiners are exempt from HIPPA regulations when conducting an investigation, so the records are readily available, but must remain confidential to the investigation (The Health Insurance Portability and Privacy Act of 1996 [HIPPA; Pub. L. 104–191, 110 Stat.1936, enacted August 21, 1996]). Ultimately, the cause and manner of death become public record, so in that respect, the medical information of the decedent will become known. The best single source for medical information on a patient is the primary care physician (internist or gynecologist for women) or family practice physician. Nurse practitioners or nurses working in the office are often very helpful sources. In an ideal situation, the physician remembers the patient well, or remembers the patient after reviewing his or her own office chart. The pathologist reviews the medical chart and other written information. In addition, it can be useful to interview medical professionals involved in the care of the patient. (See Video 2.1.)

Mental Health History

The psychiatric history should be actively sought. Previous suicide attempts, a history of severe depression or bipolar disorder, or schizophrenia, or any psychiatric hospitalizations are all germane to the investigation. Schizophrenic patients may become overtly psychotic and show bizarre behavior when medication levels are low. Severe depression can lead to suicidal thoughts and actions. Substance abuse can complicate and worsen the disease, and start a cycle ending in death from overdose (Figure 2.18).

Illicit Drug Use

Drug use and drug-seeking behavior place individuals at high risk for violent death. A history of abuse of a specific drug helps direct autopsy toxicology. Cocaine, for example, has a short half-life in the blood, but traces can be found in bile for a longer time. A special bile cocaine test can be ordered if cocaine use is suspected. Finding a syringe at the scene of a heroin overdose allows the injected drug to be tested, alerting authorities to lethal drug concentrations or combinations. Needle tracks are often visible (Figure 2.19). Synthetic marijuana or "spice" has a varied chemical composition; therefore, it is important to alert the toxicologist that "spice" might have been smoked or ingested, so that special testing can be performed. Individuals under the influence of "spice" can exhibit bizarre behavior, ending in a tragic death.

Ethanol Use

As the reader probably knows, a large proportion of cases that fall under the purview of the coroner or medical examiner involve a history of ethanol use. Acute alcohol toxicity is death from drinking excessive alcohol in one sitting (the blood alcohol concentration is greater than 0.40%, or as low as 0.25%–0.30% if the individual survived as comatose for some period; see Di Maio and Di Maio, 1989). Chronic alcoholism causes cirrhosis of the liver, and death often results from bleeding esophageal varices or other medical complications. In chronic alcoholics, a sudden halt in the intake of alcohol can cause delirium tremens, seizure, and death. Alcohol intoxication decreases judgment, reaction time, and other mentation; it also diminishes motor skills. These effects of alcohol are often factors in all types of deaths—homicide, suicide, accident, or natural. As with alcohol or any drug that can significantly alter behavior and cause serious cardiorespiratory depression, a complete history of possible use and full toxicologic examination are essential to explaining the death.

History with Law Enforcement or Incarceration

Law enforcement officials will usually provide this history to the pathologist, if the information is available. Past incarceration for drug charges, for example, can be helpful. Previous incarceration means that fingerprints, tattoo photos or descriptions, and facial photographs are available (Figure 2.20). These can be useful in confirming the identification. If an individual has been incarcerated, a detailed medical and psychiatric history is usually present. An individual's interaction with the legal system may help explain the circumstances of death. Outstanding arrest warrants, charges, or impending trials, for example, might help explain a suicide.

Other Investigative Questions or What Questions the Autopsy Can Answer

Through the investigation and the subsequent autopsy, the goal is always to answer the numerous other questions (Adelson, 1974) that arise, including the following:

- What was the date and time of death?
- What was the location of death?
- When and where was the deceased last seen alive?
- When and where was the deceased injured?
- What was the location and position of the body at death?
- How was the deceased injured and killed?
- What killed the deceased?
- Who killed the deceased?

This book will explore and illustrate how the death investigation and the autopsy serve to best answer these questions, although some of these questions may only be partially answered.

Figure 2.1 Hard contact entrance gunshot wound. The patterned abrasion at 10 o'clock and the red abrasion ring around the wound was produced by the gun barrel and sight contacting the skin when the gun was fired. Around and inside the wound, the black material is heavy soot. The finding of a hard contact wound on the chest of this individual supports the theory of suicide.

Figure 2.3 Fire victim. This victim obviously cannot be identified by visual recognition; therefore, the investigation must begin searching for a dental history. If there is a good idea of the identity of the purported victim, then family, friends, and personal items should be enquired about a dental history.

Figure 2.2 Gun-induced laceration and soot deposition of the hand. The mechanism of the pistol produced a laceration of the hand. Soot was also deposited on the hand and fingers. These findings indicated that the gun was in the hand of the victim and supports the theory of suicide for this victim.

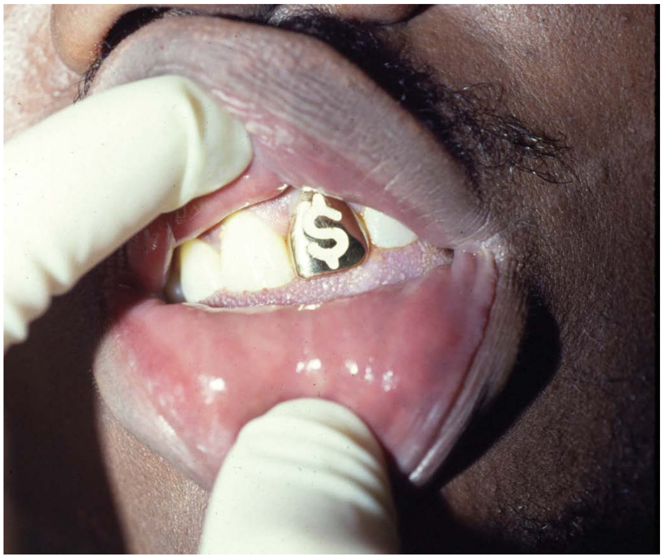


Figure 2.4 Dental cap. Unique dental appliances are often useful in helping confirm the victim's identity.

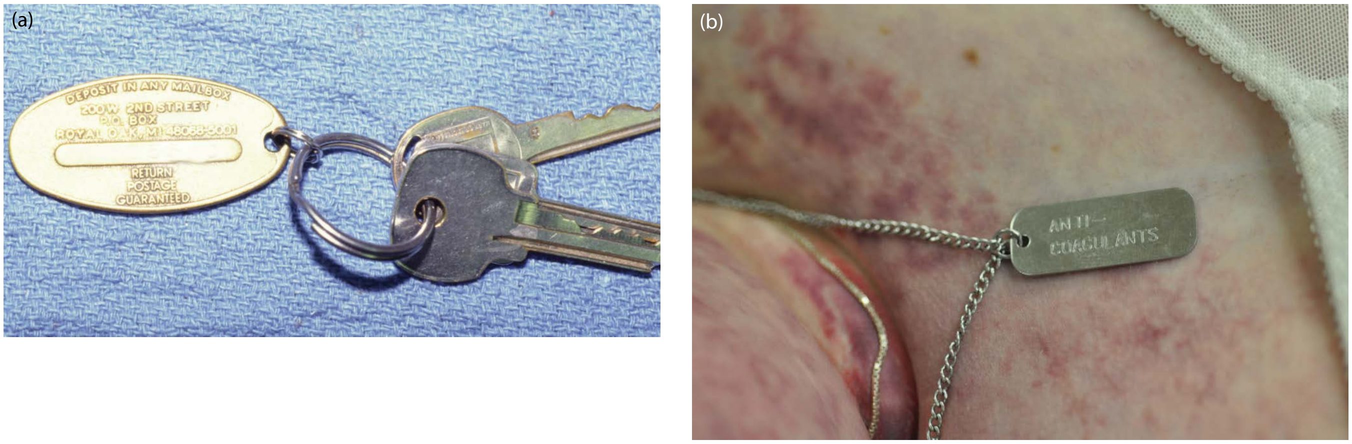


Figure 2.5 Keys found in a victim's pocket. Personal effects that are unique can help confirm an identity. **(a)** These keys were marked with a unique serial number, registered to the individual (numbers sanitized). **(b)** Medical bracelets and necklaces can support other identifying information and give insight into the medical history.

Figure 2.6 Unique tattoos. Tattoos are currently very common and serve as a very good method of identification, especially when there are four or more unique tattoo matches from reliable descriptions. Persons who have been incarcerated usually have descriptions or photos of tattoos on record. Friends, family, or social media pages are often helpful in matching tattoos for identification purposes.

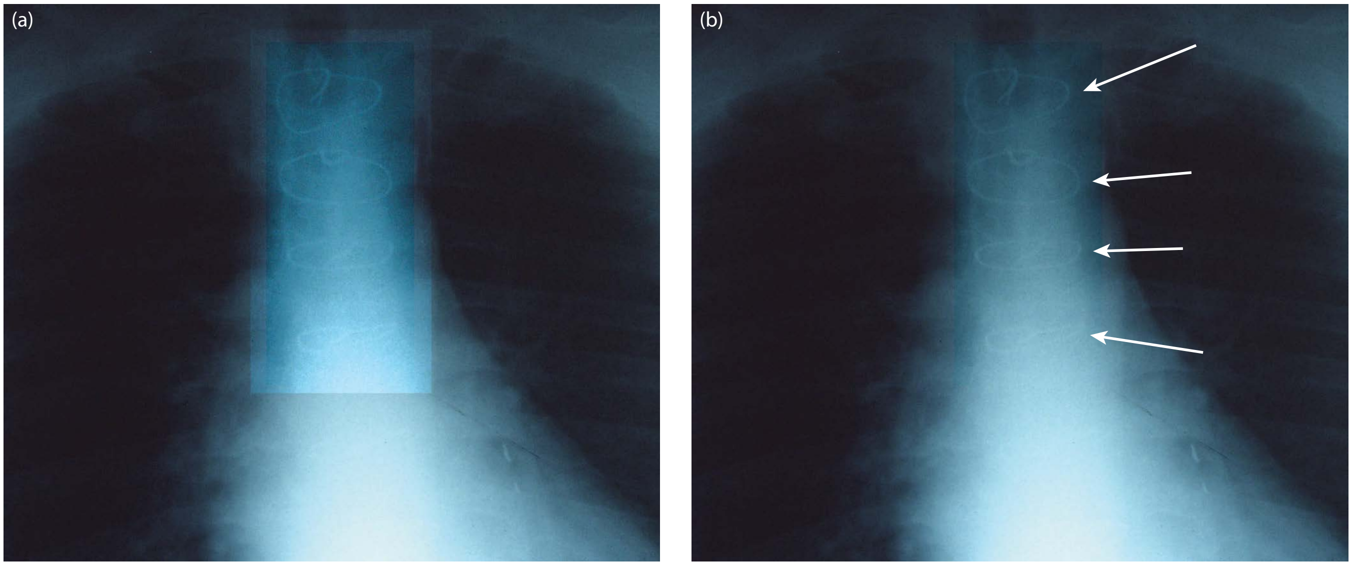


Figure 2.7 Radiograph of surgical sternal wires. Surgical wires and devices, when somewhat unique, can aid in identification when old comparison films are present. The old comparison film **(a)** shows an almost identical twisting pattern to the autopsy film **(b)**.

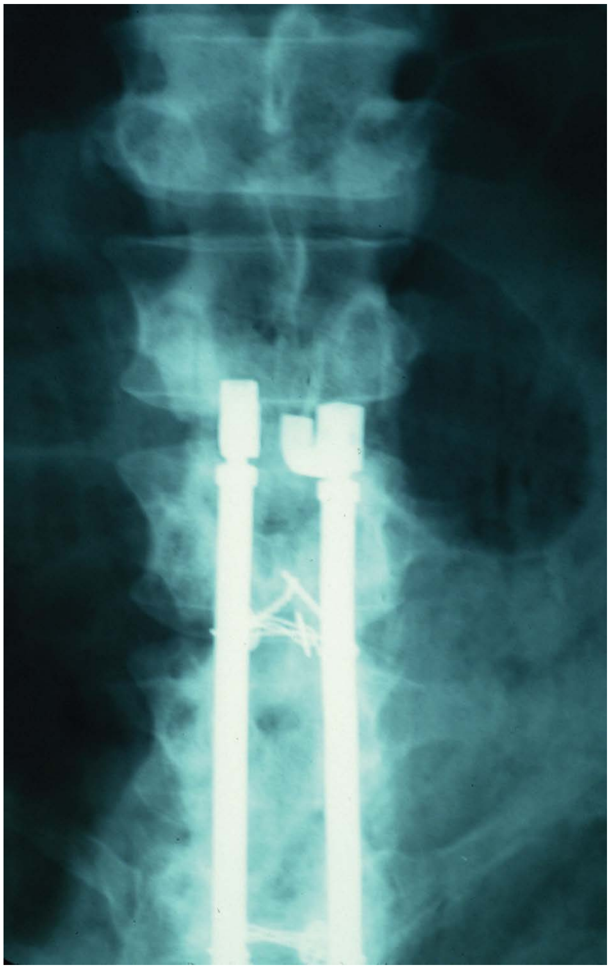


Figure 2.8 Radiograph of spinal rods. Unique surgical appliances are useful in making an identification. Radiographs of the body can be made for comparison. In addition, serial numbers on the device can be compared with previous medical records.

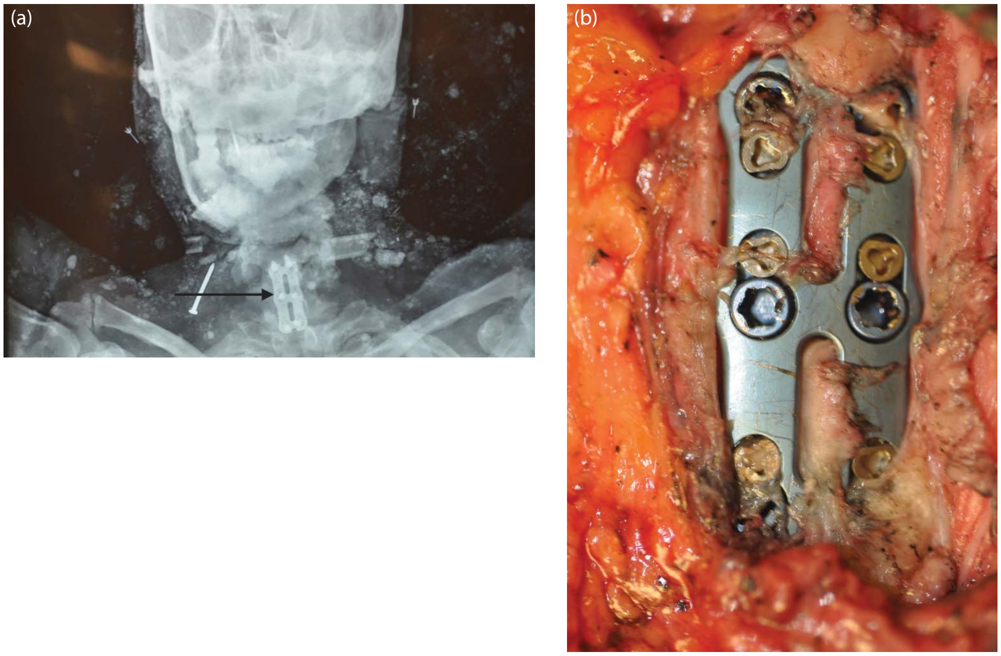


Figure 2.9 (a and b) Identification by neck plate and screws. Postmortem films of the neck show a plate and screws. Inquiry reveals the purported victim had neck fusion surgery. Medical records can be checked for old radiographs (x-rays), plate and screw brands, and serial numbers.

Figure 2.10 (a and b) Postmortem fingerprints. Obtaining postmortem fingerprints by experienced technicians is essential in all homicides or potential homicides.

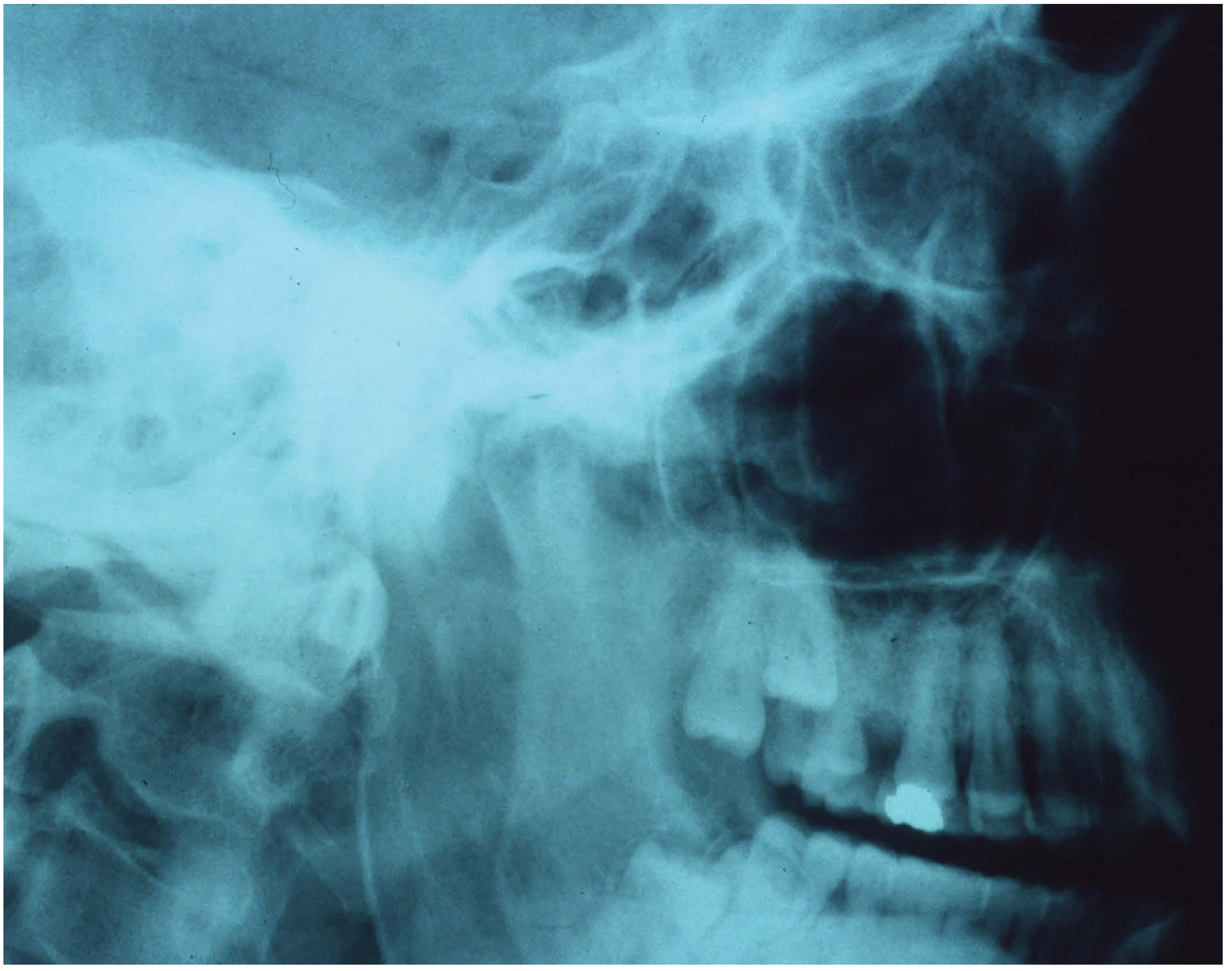


Figure 2.11 Skull radiograph with dental amalgam. A lateral skull film, as shown, or multi-angle "Panorex" films can be compared to premortem films. Such a comparison and identification is the exclusive purview of the forensic odontologist.

Figure 2.12 Premortem dental radiographs. Premortem radiographs obtained from the dentist of the purported victim are compared with autopsy dental radiographs.

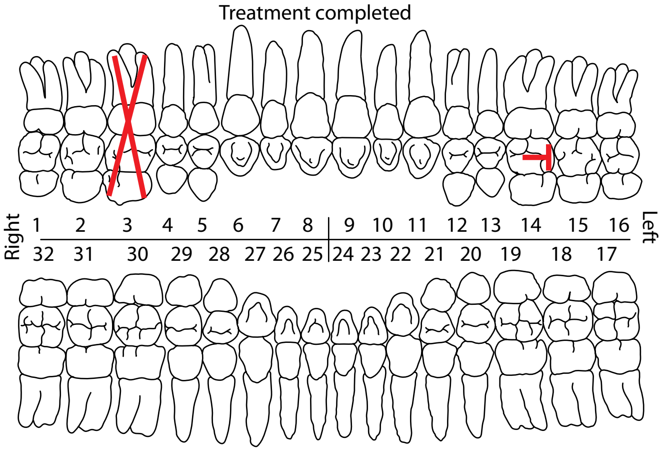


Figure 2.13 Premortem dental charts. Premortem dental charts can be compared with the teeth at autopsy to make an identification.

Figure 2.14 Electrical injury of the fingertip. The point of entry or exit of an electrical current traveling through the body often results in a burn. A history of an electrician working on electrical equipment prompts a search for such an injury. The sole of the foot is another common site of injury.

Figure 2.15 Medical records. The time spent studying medical records is not wasted, as one learns a great deal about the decedent, as well as his or her medical problems. Medications, allergies, previous surgery, social history, and other pearls are there to direct the investigator or the pathologist to finding the cause of death.

Figure 2.16 Medications at a death scene. The prescription medications at a death scene can tell a story of the medical history of an individual. Diltiazem (Cardizem) and high blood pressure medications indicate ischemic heart disease and hypertension. Theophylline and other related respiratory medications suggest chronic obstructive lung disease, and a recently filled, broad-spectrum antibiotic prescription indicates a recent infection.

Figure 2.17 Transdermal pain medication patch. Finding a Duragesic patch on this patient alerts the scene investigator and pathologist to search for more medications and a medical history. Perhaps the decedent was a pain management patient, and so was likely taking other pain medications. The pathologist can alert the toxicologist to the likelihood of finding these drugs.

Figure 2.18 Hesitation marks. These marks were found on a suicide victim and indicate suicide ideation. If the person avoids the suicide, these marks can heal, only to leave scars. Finding hesitation marks or scars alerts the investigator to search for other signs of suicidal thinking.

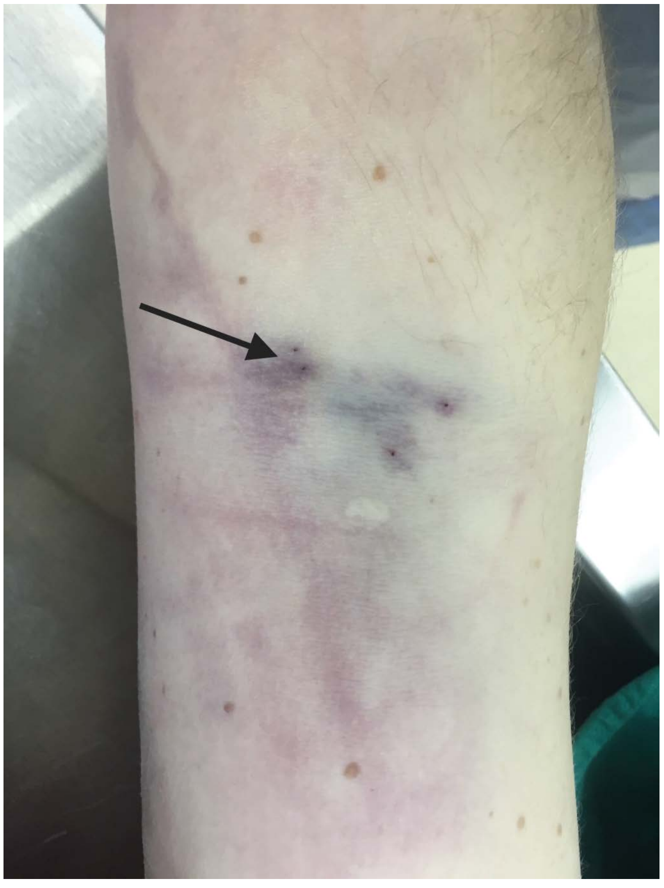


Figure 2.19 Intravenous needle puncture hemorrhages or "tracks." These tracks are indicative of intravenous drug use, and alert the investigators to ask family and friends about intravenous drug abuse, as well as hepatitis and human immunodeficiency virus.

Figure 2.20 "Jail tattoos." Amateur tattoos can indicate previous incarceration, prompting investigators to search law enforcement records for further information about the decedent.

CHAPTER 3

EXTERNAL EXAMINATION: THE PRELIMINARY EXAMINATION

SUITING UP: UNIVERSAL PRECAUTIONS

Protection of the pathologist, autopsy assistants, investigators, and medical personnel at the autopsy is not just a good idea—it is required by Occupational Safety and Health Administration regulations. The required methods of protection are called universal precautions. To perform an autopsy, the pathologist and the assistant wear hats, masks, gowns, shoe covers, mesh or "cut" gloves, and latex or vinyl gloves (Figure 3.1). Some facilities use vacuum-assisted saws to gather bone dust from skull and rib sawing. All cases are treated as potentially infectious from blood-borne and other pathogens. Although pathologists handle those cases that are known to be infectious with care, they must not be casual about the routine case that can harbor a latent hepatitis virus or human immunodeficiency virus, for example. All cases need to be treated as potentially infectious.

BODY STORAGE

The body must be stored in a secure cooler, preferably under lock and key (Figure 3.2). Only a limited number of individuals should have the key. A complete log sheet of the body's arrival time and all encounters with the body should be maintained indefinitely. This log should include all valuables found on or with the body. Any personal item that is not considered to be evidence should be logged, described, and retained for the family. Items that appear to have no value to the investigator might have value to the family, so care of these items is recommended. If lost, cheap trinkets can become expensive items for the facility to replace (Figure 3.3). Valuables can also become evidence. The watch in Figure 3.4 was broken by a golf club used to attack the victim. It was thought to have been broken at the time of the assault, a rare occurrence that makes the watch a valuable piece of evidence.

OPENING THE BODY BAG

Once everyone is properly suited up for protection from blood-borne pathogens, the body bag may be opened. Identification tags are placed on the body and the bag at the scene. Tags placed on the outsides of bags can be lost, so tagging the body directly is essential. The body is placed in a clean plastic body bag (Figure 3.5). Some pathologists recommend that the body be wrapped in a clean white sheet, since trace evidence can be lost in the large body bag. This sheet is carefully examined at the autopsy.

TRACE EVIDENCE

For the purpose of the autopsy, trace evidence is any visible or invisible substance, material, or object that is present on, in, or around the body and has potential value as evidence. Obvious trace evidence that could degrade over time or be lost in transport will be collected at the scene. Common objects collected at the scene include hair, small fibers, or paint flakes that could easily be lost. Since lighting is often poor at the scene and the setting often inappropriate, trace evidence is best taken to the autopsy suite (Figure 3.6). One method of preparing the body for transport is to drape a clean sheet over the body and then place it in a clean body bag.

The hands of the deceased are also bagged (preferably with paper bags) at the scene in suspicious deaths. Trace evidence has a higher chance of being on the hands, presumably because the victim grabs or contacts the perpetrator in some way that transfers trace evidence, such as hair, skin, or grass, to the victim's hands (Figure 3.7). As a practical matter, if trace evidence is clearly visible at the scene and is in danger of being lost, the evidence should be collected on the spot. In most cases, it is much better to collect the trace evidence at the autopsy, where the lighting is better and the environment is more controlled. Bagging the hands allows for continuity of the evidence from the scene to the autopsy and can yield DNA, fibers, or other evidence. Protecting trace evidence on the hands is a standard, commonly accepted practice, and is an expectation of juries and courts. If the hands are not bagged or otherwise protected, defense attorneys can use this omission to cast doubt on the thoroughness of the entire death investigation. However, in cases of obvious contamination of the hands, such as when the victim is taken away in an ambulance, there is not much point in bagging the hands.

CLOTHING AND VALUABLES

The clothing of the decedent is also evidence and may contain additional trace evidence. To protect all evidence from contamination or loss, and for practical reasons, the clothing is not removed in the uncontrolled environment of the scene. An exception to this rule is made in rare cases when moisture could alter a substance on the clothing; for example, condensation may form in the body bag when the body is placed in a cooler.

The clothing can be quite helpful in a death investigation, since it is intimately associated with the body. For example, the range of fire associated with a gunshot wound can be determined from soot or unburned gunpowder deposited on the shirt a victim was wearing. Unburned particles from the weapon will tattoo the bare skin. If clothing intervenes between the weapon and the skin, the majority of the unburned particles form a pattern on the clothing, with very few particles going through the clothing to the skin (Figure 3.8a–c). This clothing can be analyzed by a forensic scientist, who can estimate the range of fire of the weapon and the width and configuration of the pattern correlated to the distance of the shirt from the weapon. With rare exceptions, clothing should not be altered, removed, or cut at the scene, and it should not be cut at all in a homicide case. Clothing can contain unusual evidence (Figure 3.9), and therefore should be carefully removed in a controlled environment.

To save the life of an individual, clothing is often cut, altered, or removed at the scene of a violent death by first responders, such as paramedics. Removing the clothing is part of the routine examination of the patient, especially a victim of trauma. If the body is removed from the scene and taken to the hospital, the body is often fully undressed, possibly irreversibly altering, losing, or contaminating any trace evidence. Hospital personnel must save the clothing so that the death investigation agency can retrieve it. Even if cut, removed clothing can be valuable in determining gunshot distance, for example. First responders to the medical emergency must be careful not to destroy evidence when suspicion of violent death or injury exists. Obvious bullet holes or other significant evidence on clothing should not be cut or altered if possible. Figure 3.10 shows a cut in the middle of a garment made by first responders who appropriately avoided the gunshot wounds. (See Video 3.1.)

FOUR SIGNS OF DEATH

Rigor Mortis

Rigor mortis literally means "the stiffening of death." It is a chemical reaction that forms a stable complex of adenosine and myosin of the muscle fibers, causing stiffening in a flexion position (bent). It is a chemical reaction that comes and goes. Immediately after death, the muscles become limp or flaccid. Generally within the first hour after death, the muscles begin to stiffen. Rigor mortis starts in all muscles at the same time. However, because muscle groups vary widely in size and mass, rigor mortis is noticed in the smaller muscles first, namely the jaw and the fingers. Within 3 hours, rigor mortis is observed in nearly all muscles. In checking for rigor, the jaw, arms, and then the legs are straightened out of the flexion position and the resistance is assessed. Rigor mortis is typically reported as:

- Not yet present
- Beginning in the jaw
- Beginning in the extremities
- Full rigor
- Beginning to dissipate
- No longer present

Since rigor mortis is a chemical reaction, there are many variables regarding the rate of formation depending on the environment, size of the person, and condition of the person at death. Other rigor mortis facts are listed below:

- Muscles begin to stiffen within 1–3 hours after death at 70°F–75°F, developing fully after 9–12 hours.
- A high fever or high environmental temperature will cause rigor to occur sooner.
- Rigor mortis will occur more quickly if the decedent was involved in strenuous physical activity just before death.
- Rigor mortis is detected first in the jaw, face, and upper and lower extremities, in that order. The examiner must check the jaw, then the arms, and finally the legs in order to feel if the associated joints are moveable.
- The body is said to be in complete (full) rigor when the jaw, elbow, and knee joints are immovable. This takes approximately 9–12 hours at 70°F–75°F environmental temperature.
- The body will remain stiff for 24–36 hours at 70°F–75°F before the muscles begin to loosen, usually in the same order in which they stiffened.
- Rigor is retarded in cooler temperatures and accelerated in warmer temperatures.
- When the body stiffens, it remains in that position until the rigor passes or the joint is physically moved and the rigor is broken (or decomposition occurs).
- The position of a body in full rigor can give an indication of whether or not a body has been moved after death (Figure 3.11).

Observing rigor mortis can be useful if a body has been moved after death. For example, a decedent who was killed in a sitting position, left in that position for 3 hours, and then moved will retain the stiffened sitting position. In addition, rigor mortis can be used along with the other signs of death to estimate the time of death. (See Video 3.2.)

Livor Mortis

Livor mortis is the gravity-dependent, purplish-colored settling of blood into the blood vessels and soft tissues after death. Livor mortis is best viewed in the skin. When blood is

no longer pumped by the force of the heart, it follows the force of gravity and pools in the dependent areas of the body. Vascular tone is lost after death as well, causing the blood to leach out of the small vascular channels and into the surrounding tissues. Because blood is pigmented, it eventually leaches out of the blood vessels, breaks down (hemolyzes), and stains the tissues after a period of time, forming "fixed" lividity. Since most decedents are placed in a supine position (on their backs), the livor mortis settles in the posterior surface of the body (Figure 3.12a and 3.12b). Areas that touch the autopsy table show a "clearing" of the livor. Generally, livor mortis first becomes visible by as early as 30 minutes and up to an hour after death, and it can shift or be cleared for approximately 8–12 hours. These times can vary widely. Since livor is observed visually as purplish-colored blood in the tissues, anemic individuals or those who have died from severe hemorrhage may have little or no livor. In darker-skinned individuals, livor mortis can be difficult to see. In such cases, internal organs such as the lungs can be used to assess livor.

Livor mortis that is not "fixed" can be cleared with manual pressure (Figure 3.13a and 3.13b). Any object resting against the downward portion of the body can form a pattern in the livor mortis (Figure 3.14). If a body is moved before the livor is fixed, the livor can shift, forming a second pattern. Two livor patterns on a body can be useful in predicting the movement of a body after livor mortis has formed (Figure 3.15a and 3.15b).

Fixed livor mortis cannot be cleared with manual pressure. Between approximately 10 and 24 hours after death, the blood stains the tissues and is increasingly difficult to clear. Livor can shift after 10 hours, but this shifting is increasingly difficult to see. Livor patterns can tell a story about the position of the body after death. For example, a body found in water often has no livor mortis pattern since the body was in a zero-gravity situation and was moving, floating, and perhaps tumbling frequently, all of which would evenly distribute the livor.

Carbon monoxide poisoning will cause the livor mortis to be bright red (as well as the blood), which is an important color to recognize so that carbon monoxide testing can be performed (Figure 3.16). Carbon monoxide is a tasteless, odorless gas that can be produced by furnaces that are fired by fossil fuels. Particularly in the winter, faulty furnaces may cause carbon monoxide poisoning and death. If the red lividity is not observed and carbon monoxide testing is not done, subsequent individuals living in the building are also at risk of carbon monoxide poisoning. Cold, freezing of the body, refrigeration, and cyanide poisoning causes red to salmon-pink lividity (Figure 3.17).

Algor Mortis

Algor mortis is the cooling of the body temperature after death. During life, our metabolism holds the core body temperature constant at approximately 98.6°F (37.0°C). Death and the loss of metabolism allow the body to eventually assume the temperature of the environment. Therefore, if the outside temperature is 110°F (43.3°C), the body temperature will increase. In forensic pathology, it is generally accepted that at the standard temperature of 70°F (21.1°C) between approximately 2 and 12 hours after death, the body cools at a rate of 1.5°F (0.94°C) per hour. After approximately 12 hours, the body temperature equals that of room temperature. In practice, the rate of cooling is difficult to predict because these ideal conditions are not always present, as the environmental temperature or the starting body temperature may be unknown.

Core temperature can be taken rectally or by inserting a probe-type thermometer into the liver. These practices require full-time death investigators, who are not often available in small jurisdictions. In many jurisdictions, an experienced investigator can evaluate the body for warmth to the touch, a method that is often more practical at a busy crime scene (because the body is usually dressed and the body wall must be punctured to reach the liver). Conditions in the field are rarely those of standard temperature and humidity. Factors such as air temperature, humidity, clothing, body mass, and premortem hyperthermia or hypothermia can alter the rate of cooling. If the environment is warmer than the premortem body temperature, the core temperature can increase. Algor mortis data are commonly combined with other rigor mortis and livor mortis findings and other investigative information in order to develop a range for the time of death. Despite depictions in television and the movies, there is no test that can predict the exact time of death.

Decomposition

Decomposition is the fourth sign of death after rigor, livor, and algor mortis. Decompositional times can vary widely depending on the climate. Hot, subtropical areas can produce advanced decomposition in as little as 24 hours, as compared to a northern climate, where the same amount of decomposition might take 1 week or longer. Decomposition begins when a musty, rancid odor first appears. Once this aroma is experienced, it is not easily forgotten. This odor is from processes called autolysis and putrefaction and the changes are largely due to bacteria from the body breaking down tissue. Decompositional changes then progress from greenish discoloration of the abdomen to skeletonization. The progression of changes is listed below:

1. The first change is a greenish discoloration of the abdomen, and then the discoloration spreads throughout the body.
2. As discoloration occurs, the body will begin to swell due to bacterial gas formation, which is promoted in warm weather and retarded in cold weather. Tissues swell and the eyes and tongue protrude.
3. As the body becomes bloated, the epidermis begins to slip and forms blisters, and the blood begins to degrade (Figure 3.18).
4. Degrading blood produces "venous marbling," in which hemolyzed blood "tattoos" the tissues, producing outlines of the blood vessels (Figure 3.19).

5. Purging develops. Decomposed blood and body fluids, appearing dark brown and smelling malodorous, come out of the body orifices, largely due to gas propelling the fluid along the path of least resistance. The discolored tissues and fluids should not be mistaken for blood from an injury (Figure 3.20).
6. Lastly, skeletonization may take weeks or months depending on the environment. Many bodies are discovered in partial skeletonization (Figure 3.21).
7. Exposed portions of the body decompose faster. The visceral part of the body also tends to decompose faster (i.e., the abdomen, chest, and head). When a body part is exposed because of injury, that part tends to decompose faster. Insect activity accelerates this decomposition.
8. Decompositional changes are dependent upon temperature, humidity, insect activity, and condition of the body at death (e.g., patients with infections may decompose more rapidly).
9. By way of example, if a person dies at home and the temperature is approximately 70°F, it is not unusual for decompositional changes to take 24–36 hours to appear.
10. Insects, carnivores, and other invaders can speed up the decomposition process. Forensic entomology is the study of insects as they relate to death investigation. For example, fly larvae can be obtained at the death scene, identified, and reared in incubators. The postmortem interval (time of death) can be estimated based on the fixed-time growth cycles of the fly larvae (Figure 3.22).
11. This “gas bloating” can be quite remarkable when a body that has been found in water is removed (Figure 3.23).

Decomposition is very dependent on environmental conditions. Bodies that are frozen can be preserved for a long time. Because cold temperatures preserve tissues, bodies are stored in the morgue cooler at approximately 38°F–42°F, and decomposition can be slowed for days to weeks. Warm temperatures hasten decomposition, as does high humidity. Hot, dry conditions cause mummification, or the drying out of tissues (Figure 3.24a–c).

Other Decompositional Changes

Adipocere

Fat tissue beneath the skin begins to saponify (turn into a soapy substance), particularly in moist environments. A hard, wax-like material forms, which takes a minimum of a few weeks to develop, keeping the body in a relatively preserved state for many months. Unlike normal decompositional changes, there is no green discoloration or significant bloating. The exterior of the body remains white to brown and the outermost layers of the skin slip off.

For bodies that are totally submerged in cold water, adipocere will be evenly distributed over all body surfaces. Not all bodies having adipocere are found in water. For example, bodies found in plastic bags, which provide a moist environment, may also undergo this change. There may also be a differential development of adipocere depending on whether or not areas of the body are clothed.

Mummification

Mummification occurs in hot, dry environments. The body dehydrates and bacterial proliferation may be minimal. The skin becomes dark, dried, and leathery. The process occurs readily in the fingers and toes in dry environments, regardless of the temperature. Most mummified bodies are found in the summer months or in hot, dry climates. Mummification can occur in the winter indoors, especially if the heat is turned up, creating a hot, low-humidity environment (Figure 3.24a–c). It is possible for an entire body to mummify in only a few days to weeks in the right conditions. Once a body is in this state, it can remain preserved for many years.

DETAILED EXAMINATION OF THE BODY: FOCUS ON WHAT IS *NOT* OBVIOUS

The external examination of the decedent is a focused head-to-toe examination of the body. This examination is similar to the physical examination one might get from a physician. All parts of the body are examined, from the hair on top of the head to the toenails. The pathologist spends as much time on the external examination as on the internal examination and is always looking for trace evidence on the skin and clothing and in wounds or orifices of the body. The logical tendency would be to focus first on the obvious gunshot wound or gaping laceration, but the pathologist focuses on the other areas of the body first and then on the obvious injury. Pathologists use a systematic examination process to make a detailed survey of all systems, being careful not to overlook any area of the body (Figure 3.25).

When examining an organ, tissue, or region of the body, the pathologist generally looks for:

- Traumatic injuries, both old and new
- Natural disease processes, such as tumors or atherosclerosis
- Congenital defects or deformities
- Toxicologic, thermal (burns), and chemical injuries
- Trace evidence
- Infectious disease processes
- Anything abnormal, unusual, or unexpected

In forensic pathology, a basic axiom is to “take the victim as you find him.” With this in mind, observations are made and documented both inside and outside of the body. These observations are pieced together one by one, like a puzzle. When the puzzle is assembled, we can look at a picture of the individual just before death. From this picture, we can look back and determine how a disease or injury played a role in the death.

DOCUMENTING TRAUMATIC INJURIES: DIAGRAMS AND DESCRIPTIONS

Documenting injuries is one of the principal goals of the forensic autopsy. The body is assessed from head to toe. Any injury is examined from the outside of the body to the inside and is photographed, measured, diagrammed, and described. The autopsy records must accurately depict an injury, both in a written, descriptive manner and in visual form. Diagrams and sketches are generally drawn when notes are taken; however, since most pathologists are not artists, photography is the professional standard in documenting significant injuries (Figure 3.26). It is essential that the significant injuries are well documented, both by descriptions in the report and by photography. Because another expert will likely review the pathologist's documentations in court, the forensic pathologist has a standard of care and an ethical duty to accurately document his or her observations. Failure to document major injuries adequately can also cause potential difficulties in court for the prosecution or the defense. The prosecution must prove the case beyond "a reasonable doubt." By law, defendants are allowed to examine the evidence against them, usually through their attorneys and hired experts. It is the fundamental job of the forensic pathologist to adequately document the major injuries related to the cause of death and to explain these injuries to the jury and court.

RADIOLOGY AND IMAGING

In the autopsy suite, radiographs are primarily used in routine cases to:

- Evaluate gunshot wounds to locate and enumerate bullets, bullet fragments, and other metallic objects (Figures 3.27 and 3.28).
- Examine stab wounds or puncture wounds. Occasionally, a portion of a knife, scissors, or other sharp metallic object will break off when bone is struck (Figures 3.29 and 3.30).
- Identify the decedent. Jaw radiographs are compared with dental records of the purported victim. Unique metallic implants, such as rods in the back, can aid identification (Figure 3.31).
- Investigate possible child or elder abuse by looking for subtle or healed fractures (Figure 3.32a and 3.32b).
- Find evidence in unusual deaths, such as those from explosions or airplane crashes.
- Examine severely charred or decomposed remains for hidden objects such as bullets and clues to identification (Figures 3.33 and 3.34).
- Document characteristic fractures, such as a "nightstick fracture" of the forearm, a classic blunt force injury sustained as the victim holds up his or her arm to block a nightstick attack (Figures 3.35 through 3.37).

The autopsy is much more sensitive than the radiograph in exposing fractures of certain areas, such as the skull, ribs, or hyoid bone, because the bone is directly visualized during autopsy. When viewed during autopsy, hemorrhage resulting from a fracture enhances the visibility of the fracture (Figure 3.37). Radiographs of areas not usually dissected in the autopsy, such as the face or neck, may also be useful in some cases. The radiograph is simply a tool to supplement the autopsy. Radiographs and other methods of imaging have many more uses in forensic pathology (see the references for further information).

PHOTOGRAPHY AND VIDEO AS DOCUMENTATION TOOLS

As mentioned, in addition to describing findings in a detailed written report, the pathologist must visually document pertinent injuries in cases of medical–legal significance. Digital photography is widely used and is the standard in the field. Digital files are easily stored, retrieved, and copied. Since many states have laws regarding the release and use of digital autopsy images, the files should remain secure and not viewable by unauthorized parties. Generally, to be accepted by the courts, the photographs must be true and accurate representations of what was seen during the autopsy examination.

In homicide cases, pictures are taken of nearly every step of the autopsy, from opening the bag to documenting the last injury. Injuries are photographed both before and after the wounds are cleaned. It is crucial to clean the wounds in order to remove blood or debris. Only then can the true configurations of the wounds be revealed (Figures 3.38 and 3.39). In addition, the wounds must be clearly demonstrated for another pathologist/expert to review. A jury will probably view the photographs, and a key job of the pathologist is to explain injuries to the jury. Pictures that display the injuries poorly do not aid in this communication. Bloody, unclear, or unnecessarily grotesque photographs will probably not be admitted into evidence by the court.

Although commonly used in crime scene investigations, video recording of the autopsy with the intent of recording the procedure has not been used widely. High-definition (HD) digital video can show tremendous detail, but the problem is that of having an autopsy suite equipped with the proper number of cameras and angles to show everything going on in an autopsy. This would require turning the autopsy suite into a studio with five to seven cameras at various angles. Obtaining a good audio recording is another problem. This setup would require a crew of three to four people in order to operate the equipment. Still pictures of good quality can be produced from HD footage. If HD

video of a forensic autopsy is taken, shots of evidence and injuries should be of the same type as those taken with a digital still camera, but should also include multiple perspectives. Shots from many different angles are very useful to the viewer when there are many or complex injuries (Figure 3.40). Video footage of the entire autopsy with the intent of recording the event is not a useful tool, in the author's experience. Many states have laws regulating the release and use of audio and video recordings of an autopsy. Generally, the use of audio and video recordings is restricted to the investigation and use by the court, or for specific educational purposes.

SCARS, TATTOOS, AND OTHER UNIQUE MARKS

The skin bears many marks, some unique and some not. These marks can tell us a great deal about an individual. A scar in the middle of the chest (Figure 3.41) can indicate a patient with severe coronary artery disease that required cardiac bypass grafting. A scar in the midline abdomen may indicate previous exploratory surgery (Figure 3.42a and 3.42b). Specific finger, leg, arm, or other deformities can help identify an individual (Figure 3.43). Unique tattoos or those in certain locations or combinations can also be helpful in identification (Figure 3.44).

ARTIFACTS OF MEDICAL INTERVENTION

Medical devices can give the pathologist an idea about the resuscitative or interventional procedures that have been performed on the decedent. Although these devices can move or become dislodged during transport of the body, they should be left in place by the nursing staff and others who are responsible for preparing the body. Incisions made for chest tubes, for example, could be misinterpreted as stab wounds once the tubes are removed (Figure 3.45). Needle puncture sites from intravenous (IV) therapy can be difficult to differentiate from IV drug abuse sites or fresh "tracks" (Figure 3.46a and 3.46b). Therefore, the pathologist must review the medical record and compare it with what is found on the body.

Sometimes, medical devices reveal information about the impacts of resuscitation attempts that are not written in medical records. These medical devices and their impacts on a body may affect the findings of an autopsy. For example, central intravascular lines can be responsible for vascular tears and pneumothorax; endotracheal tubes can be placed in the esophagus, causing tears; and feeding tubes can become dislodged, causing serious or fatal injury (Figure 3.47).

The role of the pathologist is to document the location of a medical device. If the placement or performance of the device had negatively affected the deceased while he or she was a patient, the pathologist should report this fact to the trauma or nursing service in the interest of improving future quality of patient care.

Common medical therapeutic or diagnostic devices and related problems can include:

- IV lines—placement can cause an artifact of hemorrhage
- Electrocardiogram pads—can cover wounds
- Cricothyroidotomy—done to produce an emergency airway; causes problems when performed improperly (Figure 3.48)
- Surgery—done emergently to save the life, but bullet and stab wounds might be altered
- Bandages—might cover key wounds (Figure 3.49)
- Sutures—must be removed to show wound configurations (Figure 3.50a and 3.50b)
- Arterial and large venous lines—because of their size, they are more likely to cause complications such as hemorrhage than small venous lines
- Defibrillators—can cause burns on the chest and be mistaken for premortem burns

Figure 3.1 Universal precautions. Proper protection of the pathologist and all assistants from infectious diseases is essential. Eye protection, mouth and nose protection, double and cut-resistant gloves, a waterproof barrier, and a long-sleeved gown keep potential infectious agents away from the "prosectors" ("those who cut") of the autopsy.

Figure 3.2 Lockable cooler. Bodies should be kept in a lockable cooler, with a registry of all valuables being kept. All activity in and out of the cooler should be logged. The cooler's temperature is kept between approximately 37°F and 45°F.

Figure 3.3 Rings on the fingers. All valuables and personal effects, no matter how insignificant, must be cataloged and returned to the family.

Figure 3.4 Broken watch. Valuables can become evidence, such as this watch that was broken during an assault. The victim (and the watch) received many blunt force injuries, a few of which were from a golf club.

Figure 3.5 Opening the body bag. The body is placed in a clean white body bag. Some wrap the body in a clean white sheet to help to contain potential trace evidence.

Figure 3.6 Trace evidence on the buttocks. In sexual assaults, trace evidence might be as fine as a single hair, as seen on the buttock here. This small, fine evidence can be lost on the transfer of the body, and is one exception to taking evidence from the body at the scene. Pubic hair from the body can be analyzed with the suspect's, such as was done in this case, producing an identification match.

Figure 3.7 Trace evidence in bagged hands. The hands are bagged in all homicides. This allows for more careful examination of trace evidence at the autopsy. This individual has a "death grip" on some trace evidence.

Figure 3.8 Gunshot of a shirt. The presence of an intervening object, such as clothing, between the gun barrel and skin can alter the soot pattern on the skin. **(a)** Dark soot can be seen on and around the hole, produced here by a shotgun. The heat from the barrel has melted the fabric of the sweater. **(b)** The underside of the hole shows a unique soot pattern. **(c)** Soot deposition is seen inside the wound. Abrasions are seen at the wound edges from the shot and the clothing fabric. Although it is *not* the duty of the forensic pathologist to issue a report on clothing examination, if the clothing is available, it should be surveyed in order to better understand the wound on the body.

Figure 3.9 Bullet in a sweater. Some articles of clothing can trap bullets. For this reason, the clothing should be x-rayed and carefully searched, so as not to lose a bullet or other trace evidence. The body bag that was used to transport the body from the scene should be searched carefully as well.

Figure 3.11 Rigor mortis. Rigor mortis is the temporary stiffening of muscles after death. The stiffening is often quite strong. The legs shown here are stiff enough to support their own weight, hanging completely off the table.

Figure 3.10 Cut shirt with gunshots. Ideally, clothing should not be cut in a homicide or potential homicide. If the clothing must be cut in order to aid in rapid resuscitation, cuts should be made to avoid altering the gunshot holes, as shown in this shirt.

Figure 3.12 Livor mortis. (a) The distribution of livor mortis is a function of gravity. The purple–red areas are livor mortis. The pale areas are "cleared" where the body contacted the table. **(b)** The decedent was found face down on a sheet, and then turned over. Note irregular linear pattern in the livor mortis, caused by creases in the bed sheets. The arms also show rigor mortis in the flexed position.

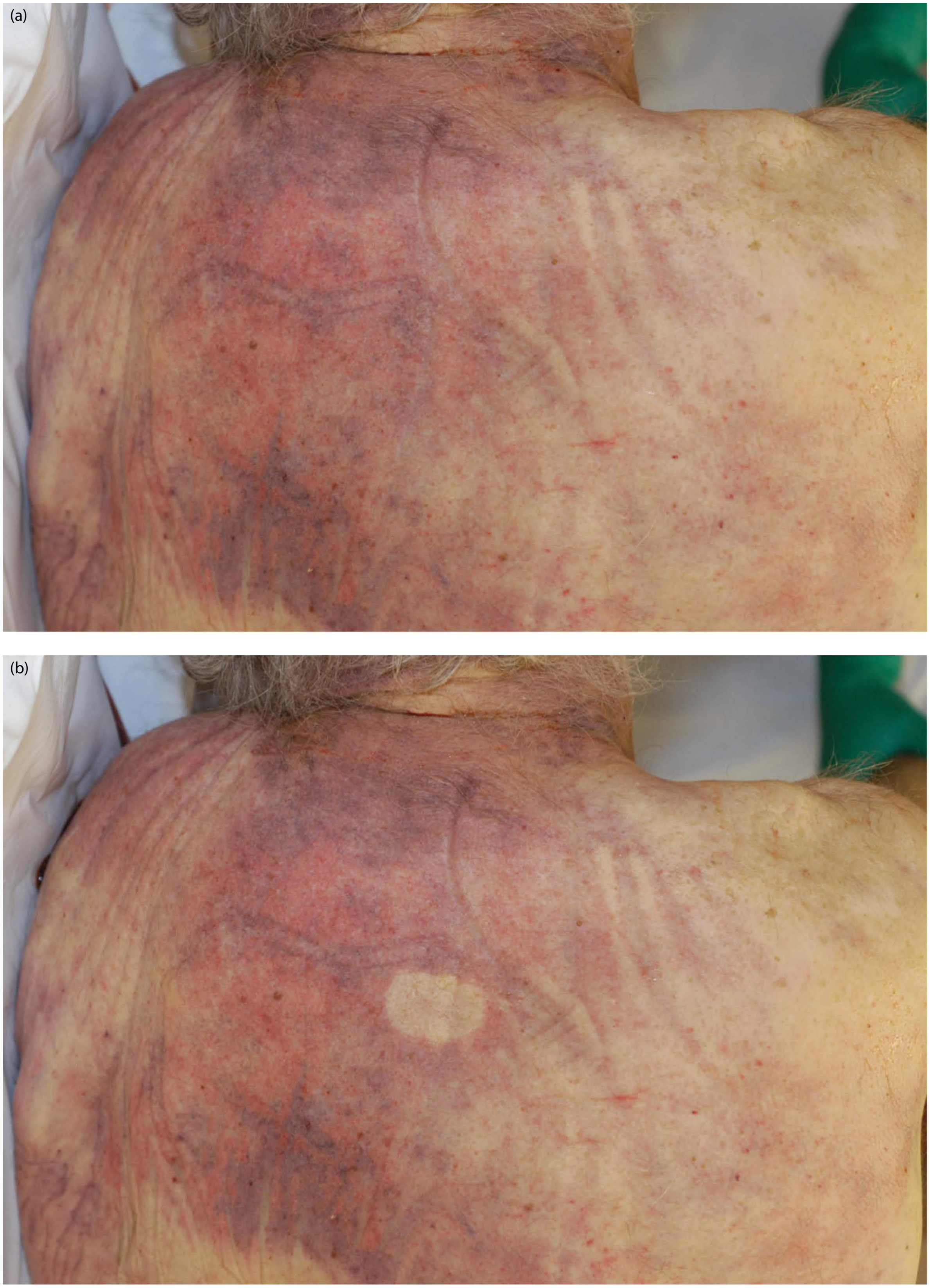


Figure 3.13 Pressure clearing of livor mortis. (a) Livor mortis can be seen on the back, on which the recently deceased victim was lying. **(b)** The pathologist has checked for pressure clearing of the livor mortis by pressing a finger on the back. The livor mortis has cleared.

Figure 3.14 Patterned livor mortis. Since livor mortis can be cleared with pressure, objects pressing against the skin when livor forms can cause a pattern. This individual was lying on an "egg crate" foam mattress. The foam tips of the mattress touched the skin and cleared the livor, while the cups of the mattress allowed the livor form.

Figure 3.15 Two livor mortis patterns. (a) This individual was found dead in a prone position (face down). **(b)** As is commonly done, the body was turned over, so that the individual was lying on their back. Generally, livor mortis can still shift, as shown, approximately 12 hours after death. In suspicious deaths, two livor mortis patterns at the scene indicate moving of the body, or even that there are two crime scenes.

Figure 3.16 Cherry-red blood of carbon monoxide (CO) poisoning. CO binds irreversibly to hemoglobin, unlike oxygen, which binds reversibly. The CO-bound hemoglobin has a bright, cherry-red color. Seeing this blood alerts the pathologist to test the blood for CO. Common household devices that can release the deadly colorless, odorless CO gas include furnaces, hot water heaters, fireplaces, kerosene heaters, and other appliances that burn fossil fuels.

Figure 3.17 Salmon-pink lividity from cold exposure and freezing of tissues. Pink lividity can be seen in frozen bodies or in cyanide poisoning.

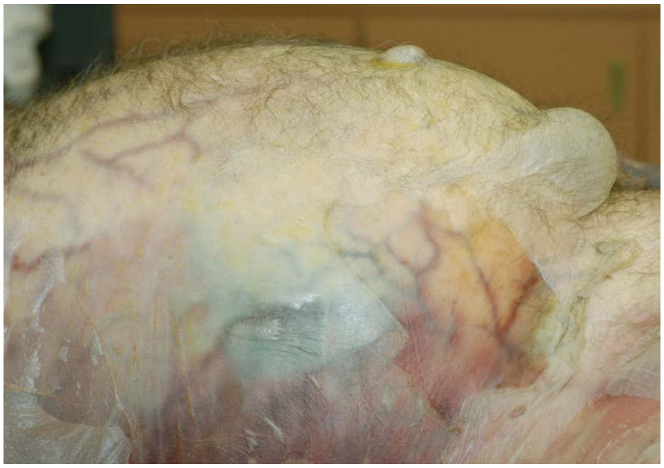


Figure 3.18 Decomposition: skin marbling, blistering, and venous marbling. These signs of decomposition, depending on environmental conditions, generally begin appearing approximately 24–36 hours after death. A putrid odor usually accompanies these signs of decomposition.

Figure 3.19 Decomposition: venous marbling and discoloration of tissues. As blood in the blood vessels begins to hemolyze and decompose, red–purple pigments stain the tissues, at times in the pattern of a blood vessel.

Figure 3.20 Decomposition: discoloration and swelling of tissues of the face, mimicking blunt force injury and "purging" of dark fluids resembling dark blood. Postmortem production of gas by bacteria causes swelling and discoloration of tissues. The gas forces dark, decomposing fluids out of the mouth and nose. These signs can resemble blunt force injuries to the untrained eye. In this case, police and scene investigators were suspicious that this individual was killed by blunt force injuries to the head, so the hands were bagged and the case handled as a homicide. The cause of death was coronary artery disease, and these are the changes of decomposition.

Figure 3.22 Decomposition: fly larvae speed up decomposition by consuming soft tissue. Eventually, the larvae will greatly diminish in number, leave when all the soft tissue has been consumed, and become flies.

Figure 3.21 Partial skeletonization. Skeletonization time depends a great deal on environment and insect and animal activity.

Figure 3.23 Decomposition: extreme tissue discoloration and gas formation in a body removed from water. Bodies removed from water show excessive gas production and tissue discoloration, owing to explosive bacterial gas production. The gas causes the bodies to bloat excessively, which can cause an explosion or sudden rupture of the tense abdomen.

Figure 3.24 Mummification. (a–c) Hot, dry conditions with low humidity can dry out tissues, causing a dark, leathery appearance. Desert climates as well as the heated indoor environments (non-humidified) can create conditions in which mummification can occur. **(b)** Hot, dry summer days can produce mummification in temperate areas, as in this suicide victim. **(c)** This individual was killed in a house in the winter in which the heat was turned up maximally, presumably to speed up decomposition and cause difficulties examining the body. Mummification tends to preserve the tissues, so the body was actually preserved very well.

Figure 3.25 Examination of the mouth. The pathologist must perform a detailed systemic examination of the entire body, being careful not to overlook any body system. During the external examination, the focus is taken away from the obvious injury and the routine head-to-toe examination is done.

Figure 3.26 **Documentation by photography.** Photographic documentation of injuries is an essential part of the autopsy.

Figure 3.28 Upon removal, bullets are photographed and placed in a unique evidence box for later identification. Some pathologists mark bullets, being careful not to alter any unique markings that the firearms examiner might need in order to perform firearms examinations (see Figure 3.27).

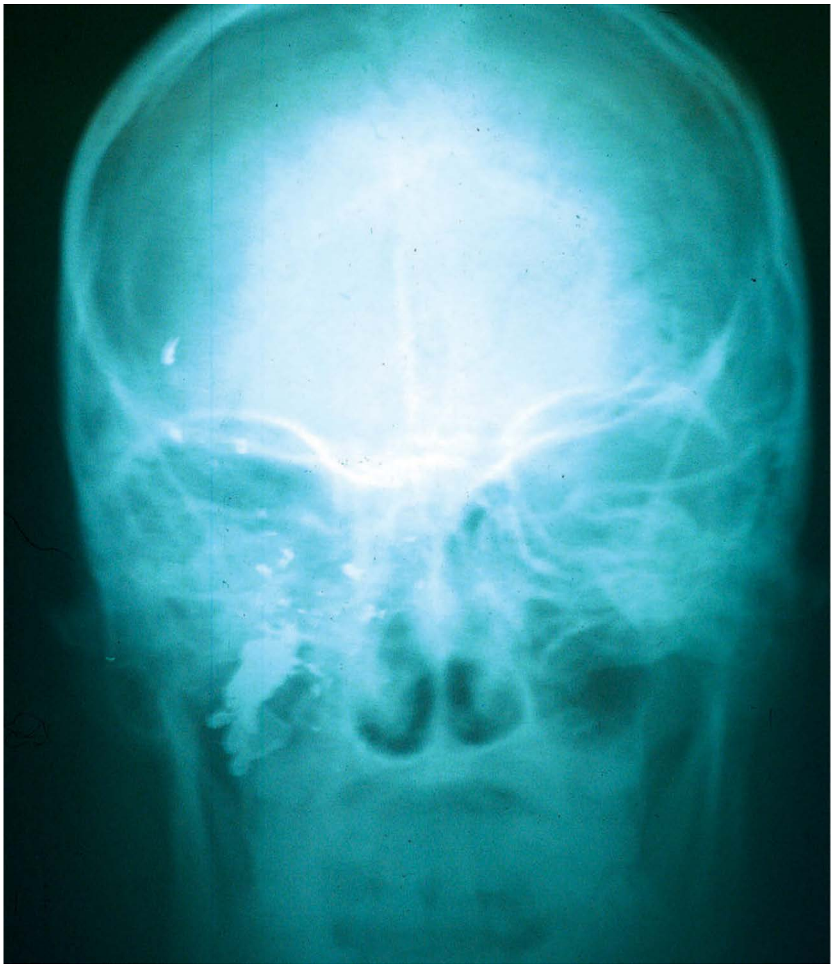


Figure 3.27 Radiograph of a skull with a fragmented bullet on removal. On the left side of the figure, just below the eye, is a fragmented bullet. X-rays are most helpful in locating bullets for removal (see Figure 3.28).

Figure 3.29 **Scissor fragment in skull.** Radiographs are not only for gunshot wounds. In this x-ray of a stabbing victim, a small metallic fragment can be seen in the middle of the figure as a white dot near the top. This victim was stabbed with a scissors, part of which broke off in the skull. The small fragment was removed at the autopsy (see Figure 3.30). Knife tips can break off when hitting bone as well. The broken fragment can be matched to a purported weapon.

Figure 3.30 Metallic fragment removed at autopsy. This is the scissor fragment that was removed as described in Figure 3.29.

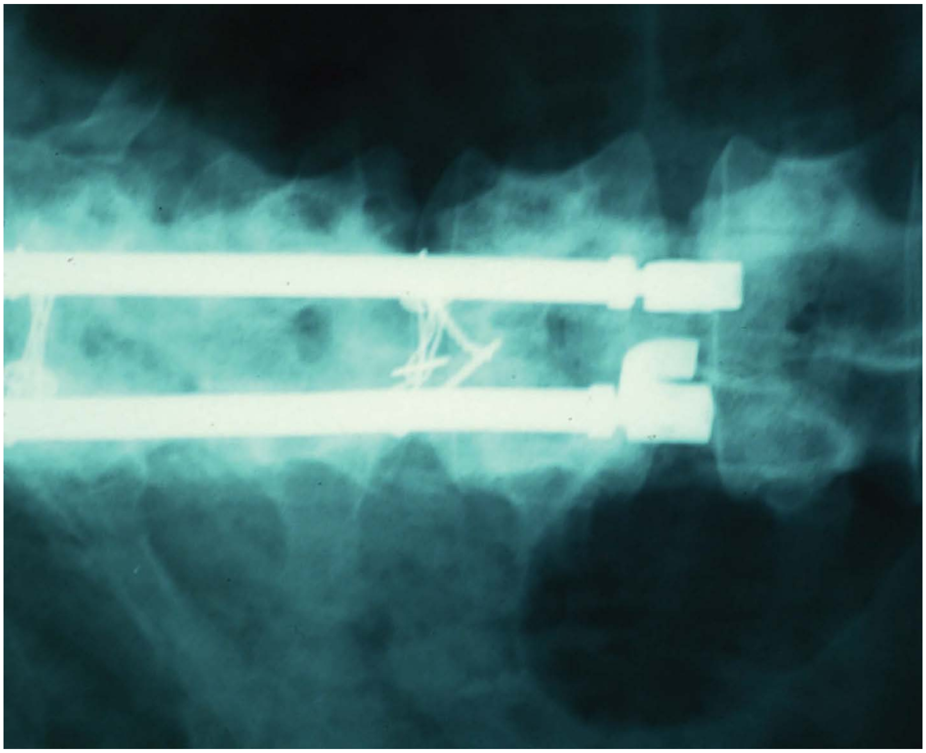
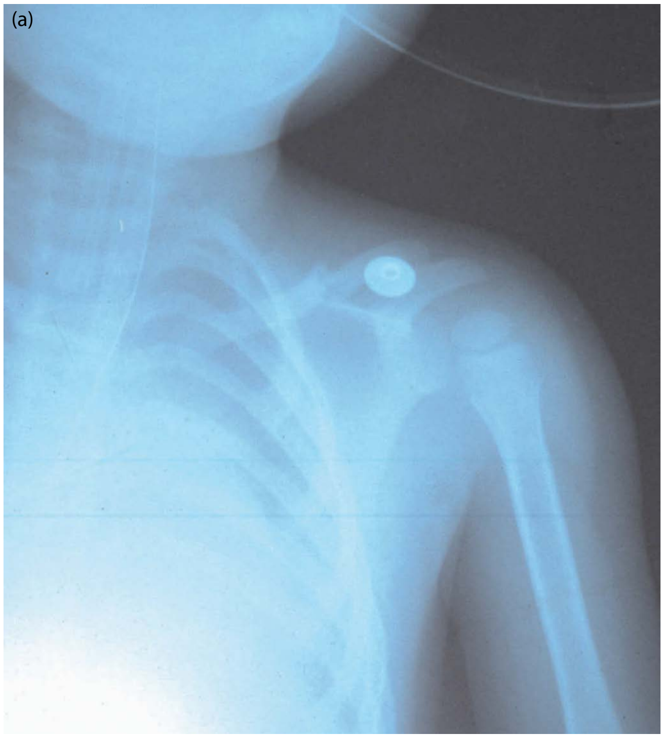


Figure 3.31 Radiograph of spinal rods. Unique prosthetic devices in the body are useful in making an identification.



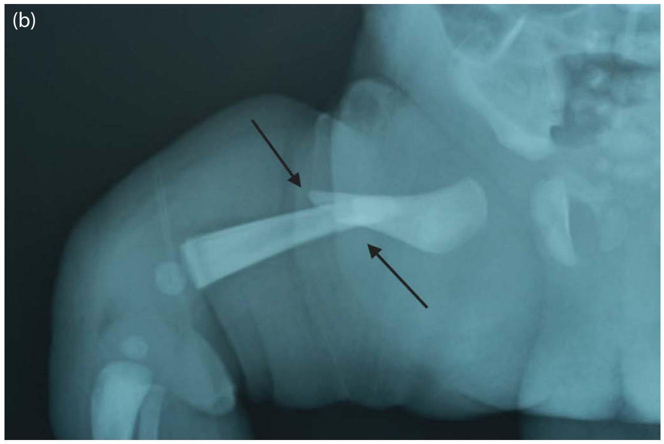


Figure 3.32 Fractured clavicle on radiograph. (a) Full-body radiographs are taken in cases of suspected child abuse. This fractured clavicle (just left of the white circular dot left by the monitor pads) was unexpected, being found in a child who had also suffered an abusive skull fracture. **(b)** This infant's femur was forcefully broken by pushing the leg downward, with the baby lying on its back.

Figure 3.33 Charred remains. The torso and head of this fire victim shows extreme thermal burns and charring. Since the individual is obviously burned beyond recognition, dental identification must be made. A forensic odontologist was used in consultation to assist in making the identification.

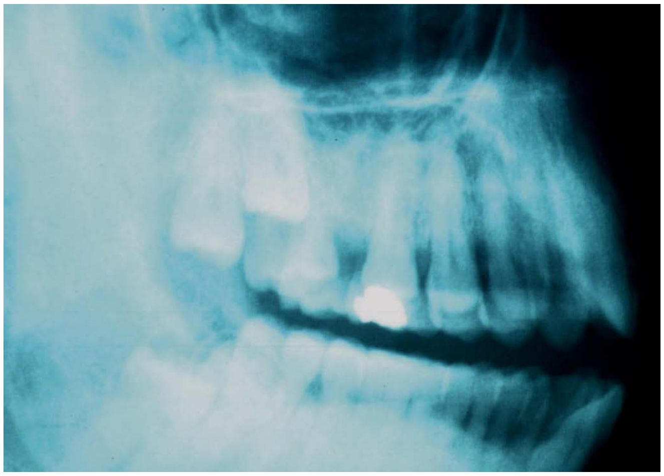


Figure 3.34 Skull film with dental filling. The forensic odontologist compares postmortem radiographs with premortem dental records in order to make the identification.

Figure 3.35 Forearm fracture. External examination of this forearm reveals a somewhat obvious deformity. The question is, what bone is fractured: the radius, the ulna, or both? The x-ray is seen in Figure 3.36.

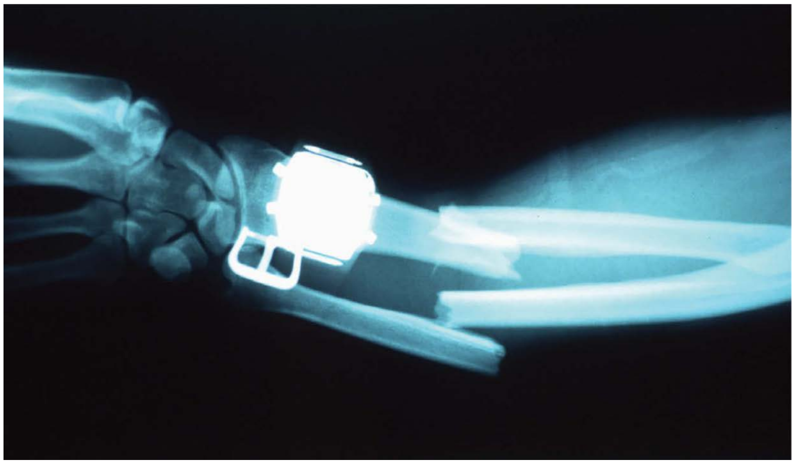


Figure 3.36 Radiograph of a forearm fracture (see Figure 3.35). The x-ray shows a fracture–dislocation of the left forearm. This injury was most likely caused by a baseball bat when the victim used his arm to shield himself from blows, also referred to as a "nightstick fracture." The victim also suffered a fatal skull fracture, most likely from the baseball bat.

Figure 3.37 Incision of left forearm fracture (see Figures 3.35 and 3.36). Incision into the fracture reveals acute hemorrhage. This confirms that the fracture was premortem. Viewing fractures directly at autopsy, especially in the skull, is more sensitive than x-rays.

Figure 3.38 Stab wounds of the chest. In deaths where there is significant hemorrhage, blood frequently covers the injuries. Blood spatter and drainage patterns are important to document and study, so these are photographed and diagrammed. After this, the body must be cleaned so that the wounds can be studied.

Figure 3.39 Stab wounds of the chest after washing away the blood (see Figure 3.38). The stab wound configurations can be seen clearly now that the blood has been cleaned away from the chest and trunk.

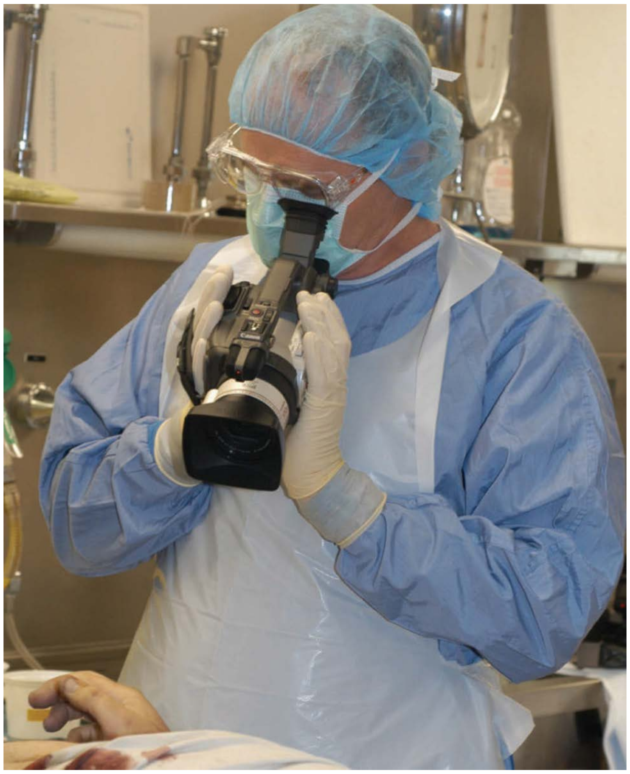


Figure 3.40 Digital video documentation. Documentation of injuries and other pertinent findings by digital video allows for viewing of the subject from many different angles. High-definition digital video has sufficient resolution to derive high-quality still pictures from the footage. This practice is useful in cases with complex and numerous injuries.

Figure 3.41 Midline chest scar. Seeing this scar suggests to the pathologist that this person has had cardiac surgery. Especially since the wound appears to be fairly recent, this finding will direct the pathologist to inquire more about the medical history. In addition, the pathologist will look internally at the chest for coronary artery disease, cardiac valve disease, and other cardiac disorders.

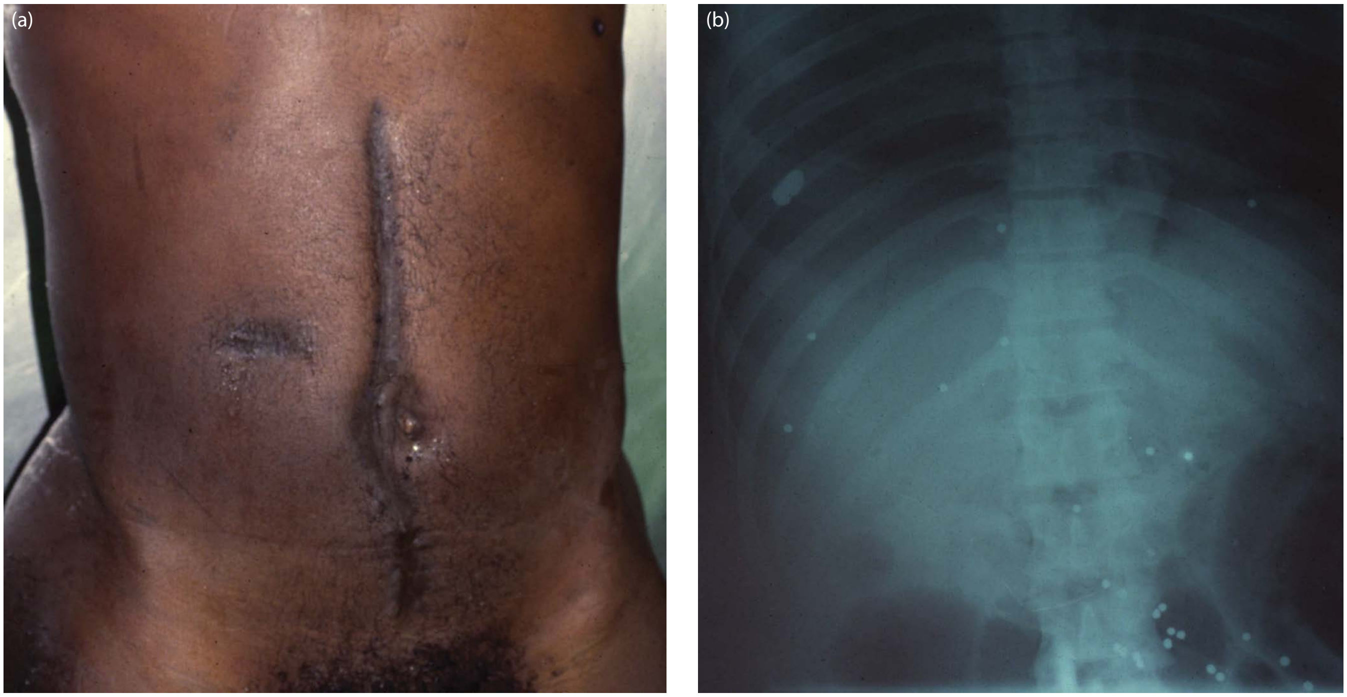


Figure 3.42 Midline abdominal scar. (a) The presence of this long midline abdominal scar indicates a previous abdominal exploratory surgery. The deceased was the victim of homicide by handgun. **(b)** This image shows the reason for the previous emergency surgery. In addition to the bullet in the upper left ribcage area, multiple buckshot can be seen in the lower half of the figure. The decedent had been shot by a shotgun in a previous assassination attempt.

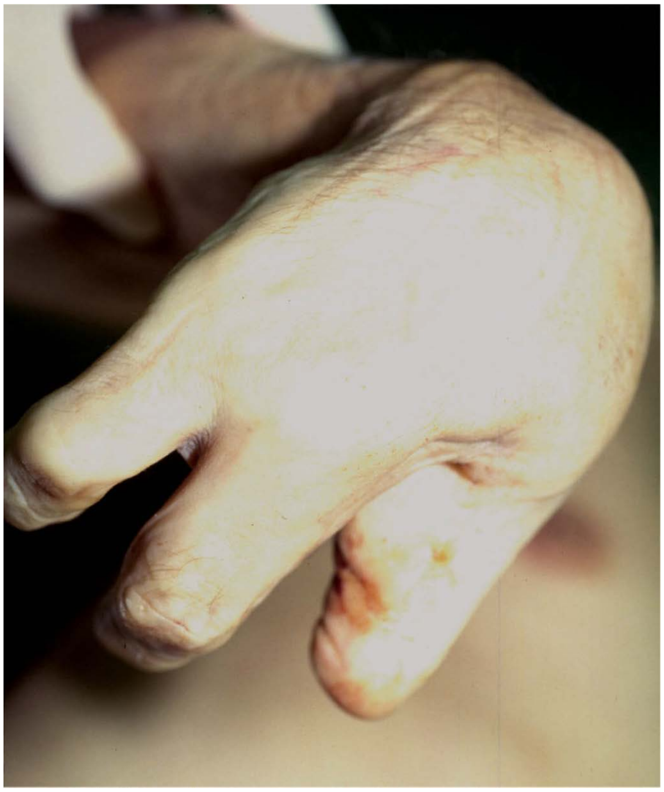


Figure 3.43 Hand deformity. Limb and body deformities are useful in identifying an individual and speak to the medical history as well.

Figure 3.44 Unique tattoo. Unique tattoos, along with their locations on the body, can be helpful in identification. Descriptions of tattoos, for example, are available in arrest records.

Figure 3.45 Chest tube. The location of chest tubes should be documented in the autopsy report and by photography. Once removed, the chest tube incision can look very much like a stab wound.

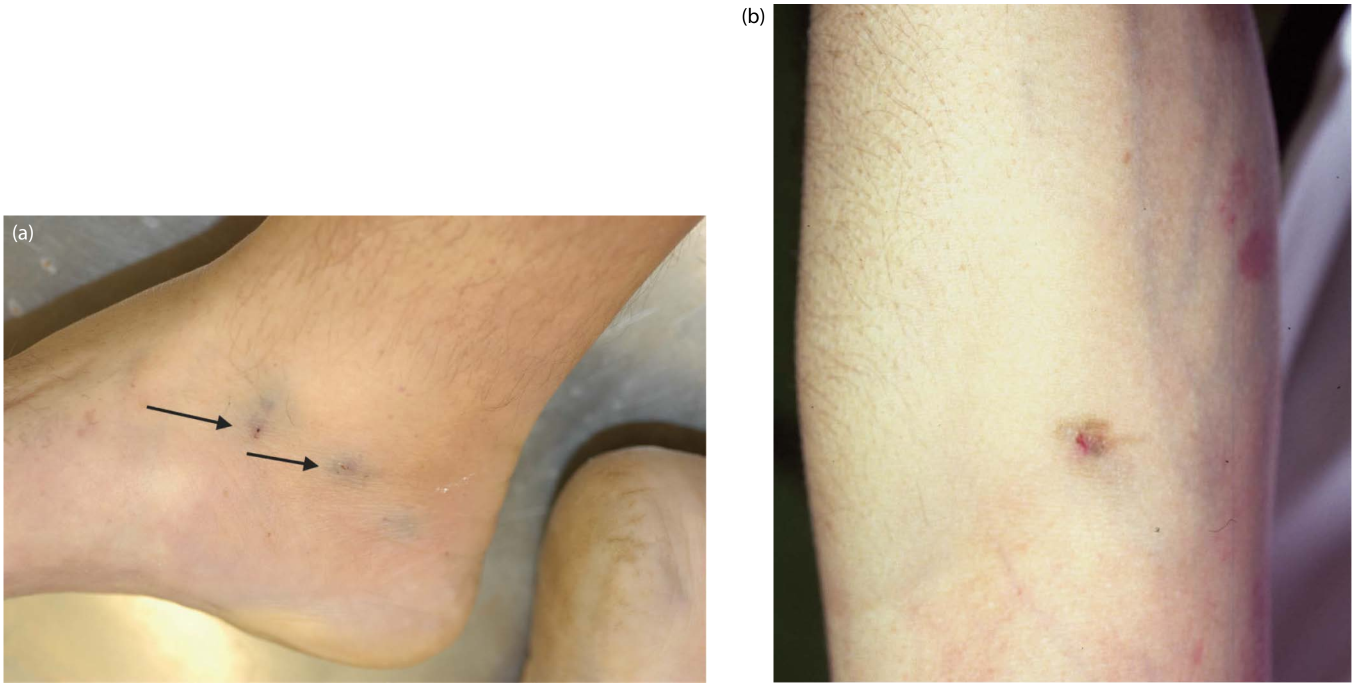


Figure 3.46 Intravenous drug abuse site. (a and b) The ankles, legs, and forearms are carefully examined for signs of intravenous drug abuse. These sites can look very much like therapeutic intravenous sites. In such cases, medical records or questioning of treating personnel can be helpful. Cutting into the site should show acute hemorrhage, as well as foreign material microscopically.

Figure 3.47 Gastric tube dislocated from the stomach. Medical devices can become accidentally dislodged, and if not soon discovered, they can cause severe, sometimes fatal complications. This individual developed fatal peritonitis as their gastric tube had been dislodged, probably for several days. Medical personnel continued to put feedings into the tube for this period of time.

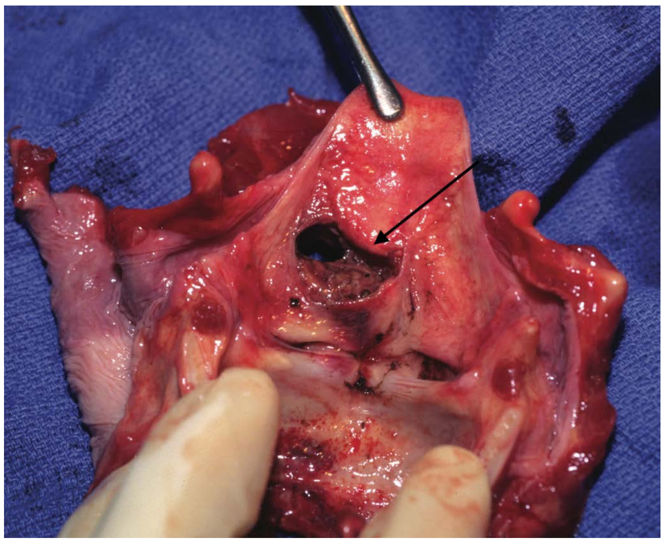


Figure 3.48 Misplaced cricothyroidotomy. When a patient in the field has respiratory failure, and cannot be successfully bagged or intubated, an emergency cricothyroidotomy must be performed. The cricothyroid membrane is below the thyroid cartilage or "Adam's apple." Improperly placed cricothyroidotomies can save the life, but can also cause vocal cord damage or other problems if the patient survives.

Figure 3.49 Medical treatment devices. After the placements of these devices are documented, they are removed. All bandages must be removed in order to expose all wounds. In the confusion of a resuscitation, key gunshot wounds can be covered with a simple bandage.

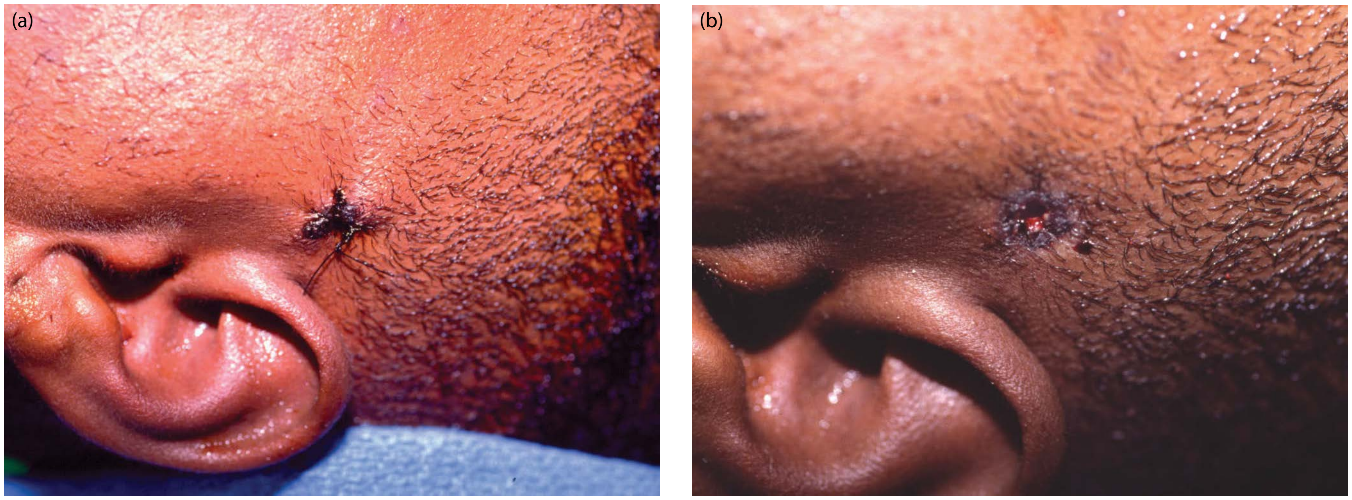


Figure 3.50 Sutured gunshot wound. (a) This gunshot wound was quickly sutured, obviously to stop the undoubted profuse bleeding during resuscitation. **(b)** The wound is easily recognized as a contact gunshot wound. Had any significant healing occurred, the wound would be more difficult to examine.

CHAPTER 4

EXTERNAL EXAMINATION: FORENSIC INJURIES

FORENSIC INJURIES AND DEFINITIONS

In the discipline of forensic pathology, injuries must be described precisely. The words used to describe these injuries have exact meanings. For example, a laceration is the tearing or splitting of tissue by blunt force. An autopsy report describing a laceration brings a visual picture of the injury to any forensic pathologist because of the descriptive language used. In addition, many injury descriptions are based on the object causing the injury. For instance, a laceration is the tearing of tissue caused by a blunt object striking or transmitting energy to the tissue. The forensic pathologist who sees a large laceration in a homicidal head injury can therefore tell the police to look for a blunt object, not a knife (Figure 4.1a and 4.1b). Described below are some common injuries, with illustrations. See the "References and Suggested Reading" section for more in-depth studies of forensic injuries.

BLUNT FORCE INJURIES

Blunt force injuries are visible changes of tissue caused by a scraping, hitting, crushing, shearing, tearing, avulsing, or similar blunt force. The appearance and severity of the injury depends on the amount of force applied, the object used to transmit the force (e.g., narrow versus broad), the part of the body injured (bony area versus soft area), and the condition of the tissue injured (muscular and fit versus fragile and diseased). Blunt force injures can be sustained if the object strikes the body, if the body strikes the object, or a combination of both. Blunt force injuries include:

- Lacerations
- Abrasions
- Contusions
- Fractures of bones
- Avulsions
- Crush injuries

Objects involved in blunt force injuries can transmit a portion of the object into the wound, such as a wood splinter from a board. The wound should be searched for trace amounts of the object that created the wound.

Lacerations (Tears)

A laceration is the tearing or splitting of skin by a blunt force object carrying force (or the person can fall or be propelled into the blunt object). Lacerations show at least three characteristics (Figure 4.2a–c):

1. Undermined margins
2. Tissue bridging
3. Abrasions at the margins

Lacerations can be straight or jagged in shape. A common error is to call a straight laceration a cut. A cut is really an incised wound, which is a sharp force injury (i.e., the tissue is cut, not torn or ripped, as described in the section "Sharp Force Injuries"). The laceration in Figure 4.3 is classified as such because it has undermined margins, tissue bridging, and marginal abrasions. The laceration is straight because the victim fell against the sharp edge of a table during a seizure.

The configuration of lacerations largely depends on the area of the body injured and the presence of underlying bony structures. Other important factors include the size, shape, surface, angle, and force of the object contacting the skin. The same object and force striking the soft, boneless region of the abdomen will cause a very different injury around the mouth area (Figure 4.4).

Abrasion

An abrasion is the denuding of skin or tissue caused by a blunt or rough object. An abrasion is commonly known as a "scrape." There are four major types of abrasions:

1. A *usual abrasion* or scrape is due to an object contacting skin or tissue parallel to its surface (Figure 4.5a).
2. A *sliding abrasion* is more linear than a usual abrasion and is caused when movement or sliding is involved. The abrasion lines show the direction of sliding (Figure 4.5b).
3. A *pressure abrasion* is due to a heavy or very forcefully projected blunt object contacting or compressing skin or soft tissue in a perpendicular fashion (Figure 4.6).
4. A *pattern abrasion* is the combination of usual and pressure abrasions, usually forming a pattern that is reminiscent of the blunt object that forcefully contacted the skin (Figure 4.7a–c).

Because abrasions involve friction between skin and the object, there is a transfer of skin to the object. This fact

can be useful; for example, the object can be swabbed and tested for DNA to ultimately determine the object that caused the abrasion. Lacerations and abrasions are often seen together in blunt force injuries. Occasionally, the objects causing these injuries leave behind pattern abrasions (Figure 4.8a and 4.8b).

Contusions (Bruises)

A contusion, commonly known as a bruise, is a *hemorrhage into skin or tissues* caused by a blunt force tearing blood vessels. The leaking of blood discolors the tissues. This purplish–red or dark–red hemorrhage can usually be seen by the naked eye. Since examining a contusion is a visual process, many factors may alter the appearance of the contusion (Figure 4.9):

- Deep contusions might not be seen except at autopsy.
- Contusions are harder to see in people with a dark complexion.
- Elderly, malnourished, and ill individuals are more likely to bruise.
- Children may be more likely to bruise on the surface, but deep bruises may be difficult to see without an autopsy (Figure 4.10a and 4.10b).
- People with cirrhosis, liver failure, and bleeding disorders will bruise more easily, as do those on certain medications (e.g., Coumadin®).
- The site of hemorrhage does not always correlate with the injury because blood drains along the path of least resistance (e.g., "raccoon eyes" in a skull fracture) (Figure 4.11).

Pattern contusion is characterized by multiple contusions forming rough patterns or outlines of the object. Objects with complex but blunt surfaces produce a pattern contusion, such as an automobile bumper (Figure 4.12a and 4.12b). Multiple contusions and abrasions can be seen in the neck and base of the jaw in manual strangulation (Figure 4.13). This pattern is produced by the assailant grabbing the neck multiple times in multiple places, implying the intent to seriously harm or kill the victim.

Special types of *hemorrhage into tissues* include:

- Hematomas: Literally "blood tumors," or large collections of blood in or around the tissue (Figure 4.14)
- Ecchymoses: Large, confluent areas of hemorrhage under the skin (Figure 4.15)
- Petechiae: Small, pinpoint, or slightly larger hemorrhages in a tissue (Figure 4.16)

Avulsion

An avulsion is the tearing away of skin and/or tissue, usually as a result of blunt force. An avulsion can have characteristics of contusions, lacerations, and even sharp force injuries if the avulsing object has a sharp edge. Avusled tissue can be hanging from the body, or it may be completely missing. Avulsions are important to recognize because a portion of skin and other tissues is likely to be present at the scene or on the weapon. Avulsion injuries are characteristic of high-speed (and therefore high-energy) transportation crashes, such as airplane crashes (Figure 4.17a and 4.17b).

Crush Injuries

Crush injuries involve tremendous forces and large objects (Figure 4.12b). The object(s) causing the injuries are usually not difficult to find due to their sheer size. Characteristics of crush injures include:

- Combination of all blunt force injuries: Laceration, abrasion, pressure abrasion, and avulsion
- Deep injuries to tissues, such as laceration of organs
- Accidental deaths, such as automobile crashes and industrial accidents
- Fracture-comminution of bones

Fractures

Fractures of bones generally require a large amount of force. Exceptions include the elderly with osteoporosis, where fractures can even occur spontaneously with normal activity, such as walking. Children and young adults have pliable bones that bend, but do not break as easily. In the extremities and elsewhere, children tend to get greenstick fractures, where the bone bends like a young, green sapling. Bone fractures are caused by *direct* and *indirect* trauma (Di Maio and Dana, 2006).

Direct fractures are classified as follows:

- Focal fracture: A small to medium force striking a focal bone.
- Crush fracture: A large force over a large area, often breaking the bone into multiple pieces (comminution) and causing soft tissue injury.
- Penetrating fracture: An object striking bone with great force in a concentrated area.

Indirect fractures are caused by forces acting outside or away from the bone. Indirect fractures include:

- Rotational fracture: The bone is twisted, causing a fracture, such as twisting the arm or leg of a child abusively.
- Traction fracture: The bone is literally pulled apart.
- Angulation fracture: The bone is traumatically bent at an angle until it snaps, leaving an angular fracture line.
- Compression fracture: The bone is compressed, causing fracture. In osteoporosis patients, the weight of the body can cause a vertebra to collapse or "compress."

SHARP FORCE INJURIES

Sharp force injuries are generally made by a sharp object cutting the skin (except for special incised wounds, such as ice pick wounds), and are commonly called "cuts." This is

as opposed to a laceration, which is caused by tearing the skin. A common mistake is to call cuts "lacerations." This incorrect classification of the wound can lead to the police looking for a baseball bat instead of a knife! Types of sharp force injuries include:

- Incised wounds
- Stab wounds
- Puncture wounds
- Defense wounds or "cuts"
- Hesitation wounds, "marks," or "cuts"
- Chopping wounds

Stab Wounds

A stab wound is a cut of the skin or other tissue that is generally deeper than it is wide, caused by a sharp object like a knife, piece of glass, shiv, or similar object. Because stab wounds involve deep arteries, veins, and organs, the mechanism of death in these cases is often hemorrhage. The configuration of a knife stab wound depends on the sharpness of the blade. Most blades are sharp on one side and dull on the other, creating a V-shaped mark on the sharp end and a blunt or pyramid-shaped wound on the other end (Figure 4.18a and 4.18b). Abrasions in and around the stab wound are caused by blunt features on the knife. "Hilt marks" are caused by the handle and the attached (finger) guard. Other features such as serrations or other adornments on the knife can leave abrasions (Figure 4.19). Unlike gunshot wounds in which a bullet can be matched to a specific gun, knives can only rarely be matched to a specific wound. Cases in which the perpetrator's fingerprints or the deceased's blood are on the knife allow matching to a specific knife. In addition, if the knife, scissors, or other sharp instrument tip hits bone, it can break off and be matched up by tool marks to the purported sharp instrument (Figure 4.20a and 4.20b). Knife length and width cannot be reliably predicted by wound measurements. Tissue is very stretchable, so even a short blade can penetrate deeply. A long knife might not have been fully inserted. However, if multiple stab wounds are present, an experienced pathologist can give a range of possible knife lengths. Absent some specific information, such as DNA, the pathologist can usually only opine that the wounds are consistent or not consistent with a purported knife (Figure 4.21a and 4.21b).

Incised Wounds

Incised wounds are generally longer than they are deep. For example, classic incised wounds are hesitation cuts seen in suicides or suicide attempts (Figure 4.22). In hesitation cuts, the victim tries to cut the blood vessels of the wrist, but lacks the knowledge of anatomy to make an incision in the proper spot. The victim stops cutting because these wrist cuts are painful. Then the victim gathers more nerve and cuts deeper, usually into superficial tendons, not the more distant blood vessels. Often, the victim gives up this method of suicide and either seeks medical care or resorts to another method of suicide.

Defense Wounds or Cuts

Defense wounds are cuts, usually incised wounds of the hands, arms, shoulders, wrists, or even the upper thighs, sustained as a result of fighting off a knife attack (Figure 4.23). The victim might attempt to grab a knife, or block the knife blows with the arm. These cuts can be quite deep, severing tendons and muscles. The word "defense" in defense wounds can be a misnomer, because these wounds can be sustained if the deceased was the aggressor and simply lost the fight.

Puncture Wounds

Puncture wounds are usually deep wounds with a punctate (point-like) entrance wound on the skin. Nails, awls, ice picks, and screwdrivers are typical weapons. Often, the side of the weapon will cause an abrasion that at least partially surrounds the wound. To cause death, many such wounds must be concentrated in a certain area, such as the heart (Figure 4.24).

Chopping Wounds

Chopping wounds are produced by weapons with at least one sharp edge, such as a machete, sword, hatchet, axe, or meat cleaver (Figure 4.25a–c). These instruments are large and have weight, which can cause blunt force injuries as well, such as contusions, abrasions, and bone fractures.

FIREARMS

Firearms fire a bullet or other projectile with tremendous kinetic energy, and when contacting the body, the kinetic energy is transferred to the skin, soft tissues, and organs. This energy produces a laceration of the tissues, including blood vessels, resulting in hemorrhage (the primary mechanism of death in many gunshot wound deaths). Other effects of gunshot wounds depend on the region of the body or organ system that is shot. Bullets striking the brain can cause laceration of vital parts of the brain, leading to near-immediate death. Gunshot wounds of the lungs can cause an air leak (pneumothorax) and subsequent death if untreated. The ferocity of gunshot wounds is such that the victim can survive the initial gunshot wound, only to die months later due to an infection or blood clot.

For many reasons, the firearm is unique among devices that can cause death. Unlike knives and blunt objects, a person can be killed without close contact. If a pattern is visible on the skin or clothing, an accurate estimate can be made of the firing distance. If the projectile (except for smoothed-bore guns) can be found, the exact weapon can be identified. A person can shoot himself or be shot by another person and the wound is identical. For this reason, the author recommends performing autopsies in all suicides by gunshot (Figure 4.26a and 4.26b). In addition, in order

to further document the purported suicide, the bullet can be retrieved for comparison to the gun. The common types of civilian firearms include:

- Revolver
- Pistol
- Rifle
- Shotgun
- Machine gun

The pistol and revolver are commonly called handguns. The revolver most commonly holds six rounds (unfired bullets) in the central cylinder. The cylinder turns as the gun is fired. The pistol is loaded by a magazine, or "clip," which may hold from seven to fifteen or more rounds (Figure 4.27a–c). Rifles and shotguns are fired from the shoulder. Rifles vary greatly in the caliber and type of round that can be fired. Bullets from high-powered rifles fragment in the body, dispersing energy and causing a characteristic "lead snowstorm" on x-ray (Figure 4.28a). Handguns and rifles have riflings in the barrels, which cut unique lands and grooves in the bullet that are specific to the exact gun that fired the bullet. Shotguns are smooth-bored guns that generally shoot shot (or BBs) (Figure 4.28b). Some shotguns, particularly those used for deer hunting, do have riflings for shooting a large projectile called a slug. The riflings make the gun more accurate by causing the bullet to spin, much like spinning a football.

Handguns and rifles fire ammunition or cartridges composed of a primer, gunpowder or propellant, and a bullet or projectile. When a firing pin of a weapon strikes the primer, the resulting explosion ignites the gunpowder. Gunpowder, vaporized primer, and metal from a gun may be deposited on the skin and/or clothing of the victim. In addition, elements from the primer may be deposited on objects in close proximity to a discharged weapon.

Gunpowder comes out of the muzzle in two forms:

1. Completely burned gunpowder, called "soot" or "fouling," can be washed off the skin (see Figure 4.26b).
2. Particles of burning and unburned powder can become embedded in the skin or bounce off and abrade the skin.

The marks on the skin are called "tattooing" or "stippling."

Gunshot Wounds

In the study of gunshot wounds, as in every other aspect of forensic pathology, the pathologist is part of a team. The pathologist is responsible for describing the wounds on the body, collecting bullets or bullet fragments, and performing the autopsy. Based on the examination of these wounds, the pathologist is asked to render an opinion on the range of fire. The presence or absence of gunpowder stippling patterns is described, and the patterns are measured by the pathologist. The firearms examiner compares these measurements and descriptions with test patterns produced by firing the purported gun. The information gathered by comparing known patterns at known distances with the unknown pattern on the body allows the range of fire to be estimated.

At the autopsy, after the body is initially examined, the wounds are cleaned carefully. Each wound is photographed, measured, and diagrammed by the pathologist. The pathologist should include the wound track (path through the body), along with a three-dimensional description of the bullet path. The bullet is recovered by the pathologist and then photographed, taking care not to damage the riflings on removal. The bullets are handled as evidence and are given to the crime scene technician for photography and cataloging (Figure 4.29). Bullet removal from a given site is best documented by photographing or marking the bullets, and then placing them into a unique labeled container. Later, the firearms examiner compares test-fired bullets from the purported gun to those found at the autopsy. The pathologist must be careful not to damage the bullets on removal.

The gunshot wounds are studied by the forensic pathologists to determine the entrance and exit wounds, as well as the wound tracks. From this examination, pathologists can determine or assist in determining the following:

- Direction of fire
- Range of fire
- Type of weapon
- Position of victim at the shooting scene (e.g., behind a door)
- Direction of the bullet traveling through the body and the organs involved

These listed findings are often helpful to investigators reconstructing the shooting event. The study of gunshot wounds and their classification takes extensive training. *Only a forensic pathologist should officially classify a gunshot wound.*

Inspecting the skin or the clothing for the characteristic patterns of burned and unburned gunpowder allows the wound to be classified by type as:

- *Hard contact* (close contact): The muzzle has been pushed tight or "hard" against the skin, forming a tight seal between the muzzle and skin, causing the heat, soot, and bullet to go into the wound. The result is most often charring of the wound edges (due to a heat of approximately 1400°F) and an abrasion of the wound margin. In bony areas where the skin is stretched, such as the forehead, the wound margins can tear, forming a stellate (star-like) pattern. Soot is then heavily deposited inside the wound. Back-spatter may be present on the weapon or shooter (Figure 4.30a–c).
- *Contact* (loose contact): The muzzle is incompletely or not quite touching the skin, so a slight rim of soot surrounds the wound. This soot can be washed away, and no stippling is seen. Less abrasion is present compared to a hard contact wound (Figure 4.31).
- *Near contact*: The muzzle is not touching the skin at all, but is within less than approximately 1 inch.

A wide rim of soot and seared skin surround the entrance bullet hole, which is much wider than with a contact wound (Figure 4.32). If any stippling is seen must be classified as intermediate range.

- *Intermediate range*: Seeing stippling or powder tattooing of the skin is diagnostic of this wound (Figure 4.33a–d). These wounds occur at muzzle-to-target distances of approximately 6 inches up to 3 or 4 feet, depending on the weapon used and the type of ammunition. There is no soot deposition or charring, only stippling or powder tattooing of the skin. Stippling is imbedded in the skin and cannot be washed off. An estimate of the range of fire can be given if the diameter of the stippling on the body (or clothing) is compared to that of the weapon when test fired by a firearms examiner.
- *Distant* (undetermined range): No soot or stippling is seen. The wound has a small "abrasion collar" produced by the bullet scraping the skin circumferentially as the skin is perforated (Figure 4.34).
- *Exit wounds*: Exit wounds vary greatly in appearance. They can be irregular, stellate (Figure 4.35a and 4.35b), slit-like, and, rarely, round. Round exit wounds can resemble entrance wounds before they are cleaned. Exit wounds do not have an associated circular abrasion at the entrance hole. While exit wounds are generally larger than entrance wounds, some exit wounds are the same size or smaller. The pathologist does not commonly give opinions about entrance and exit wounds at the scene, where the lighting is often bad and the wounds are bloody. Opinions regarding gunshot wounds are only given after a complete autopsy.

Shored Exit or Entrance Wounds

Shored wounds are characterized by abrasions and contusions surrounding the gunshot wound, often imparting an irregular configuration to the wound (Figure 4.36a and 4.36b). When the bullet exits or enters the skin, objects next to the skin in the region of the wound track can strike the skin and cause a secondary wound, called a shored exit or entrance wound. Common objects producing this effect include a wall or floor, leather or very thick coats, belts, bras, wallets, and jewelry.

Graze and Tangential Wounds

When a bullet strikes the skin at an angle insufficient for penetration into the deep subcutaneous tissue, the skin is torn and abraded. The tears often point in the direction the bullet traveled (Figure 4.37).

Entrance and Exit Wounds of the Skull

The skull, particularly the convexity of the calvarium (top), provides special clues and indications regarding the direction of the gunshot wound. The bullet cores out a wedge of the thick skull bone in front of the bullet track. The narrow tip of the wedge is where the bullet starts the core. As it goes through the bone, it cores out a wedge, the base of which is the end of the bullet track. Therefore, an entrance wound of the skull (Figure 4.38) shows "inward beveling" and an exit wound of the skull shows "outward beveling."

Secondary Target Wounds and Trace Evidence

If the bullet goes through any object before hitting the victim, parts of this object may be carried into the wound. For example, if the victim is shot through a blanket, a portion of blanket may be in the wound or stuck in the surrounding skin (Figure 4.39). Glass and clothing are common secondary targets.

Shotgun Wounds

Shotguns fire shot, producing a dispersed pattern, the width of which depends on the choke of the gun (Figure 4.40a–e). The shotgun wound produces additional wounds that give information regarding the range of fire. While the soot and stippling patterns are similar to those described above, the spread of the shot and the wounding pattern can also aid in estimating the range of fire. Portions of the shotgun shell packing (wadding) can also be found in the wound, up until a range of fire of approximately 5–6 feet. A more exact range of fire is obtained by test firing the shotgun. Patterns of shotgun wounds can be generally described as follows:

- Contact to approximately 2 feet: A single, round entrance hole is seen, with all shot and wadding found within the wound.
- 2–4 feet: The shot begins to disperse and a single irregular, scalloped "rat hole" is seen. Wadding is usually found in the wound.
- 4 feet to approximately 10 feet: The shot disperses further, with satellite holes surrounding the central hole. The wadding is probably not in the wound, but might cause an abrasion if it strikes the skin.
- 10 feet and beyond: The shot has dispersed such that a central hole is no longer seen, only individual entry wounds of each shot.

Shotguns that fire slugs may or may not be rifled. Once a slug enters the body, it usually does not exit. Riflings are only seen on those shotguns that are used to fire a slug. If the shotgun shell is found, firing pin tool marks can be matched to the shotgun in some cases.

Miscellaneous Firearm and Gunshot Wound Facts

The caliber of the wound cannot be predicted by the size of the entrance wound. Wound sizes can vary depending on

the energy of the bullet, the type of bullet, and the region of the body receiving the wound.

The forensic pathologist determines the wound tracks and describes these in the final report. Wounds that cause severe injury or death primarily do so by hemorrhage or exsanguination (Figure 4.41a–c). The energy imparted by the bullets lacerates large and small blood vessels. Hemorrhage is not the only factor. Gunshot wounds of the brain cause immediate neurologic damage. Gunshot wounds of the lungs cause pneumothorax, so the lungs collapse, making it very difficult for the victim to breathe. Injuries to the spinal cord and legs can make it difficult for the victim to flee the scene of the shooting.

All gunshot wound cases should be x-rayed. Even if there is an exit wound, x-rays should be performed. Part of the bullet, such as the jacket (which can contain riflings), can and often does remain in the body. The body should be x-rayed with the clothing on because clothing can trap bullets (Figure 4.42a–c). Cartridge casings have been found in the hair at autopsy (Figure 4.43a and 4.43b).

The death scene must be examined for bullets and cartridges. In many jurisdictions, this task is performed by law enforcement personnel or crime scene technicians. It is useful to hold the crime scene until after the autopsy because after the complete examination of the wounds, some bullets might be missing.

Figure 4.1 (a and b) Lacerations of the scalp. Lacerations are often erroneously called "cuts." When the skin contacts a blunt object or surface with sufficient force, the skin is torn or ripped. This tearing produces distinct configurations in the wound. Cutting the skin with a sharp object produces clean margins.

Figure 4.2 Laceration of the scalp with marginal abrasion. (a) Blunt force striking the skin with sufficient force tears the skin, resulting in tissue bridging, undermined margins, and a marginal abrasion. **(b)** This victim fell on a concrete step. **(c)** Objects with weight and mass, such as a hammer, being propelled against the skin can cause complex lacerations and fractures.

Figure 4.3 Laceration of the forehead. Do not let this injury fool you! It looks like a sharp force injury or cut because it is straight. Careful observation, however, reveals tissue bridging, undermined margins, and marginal abrasion. This victim fell against a table edge.

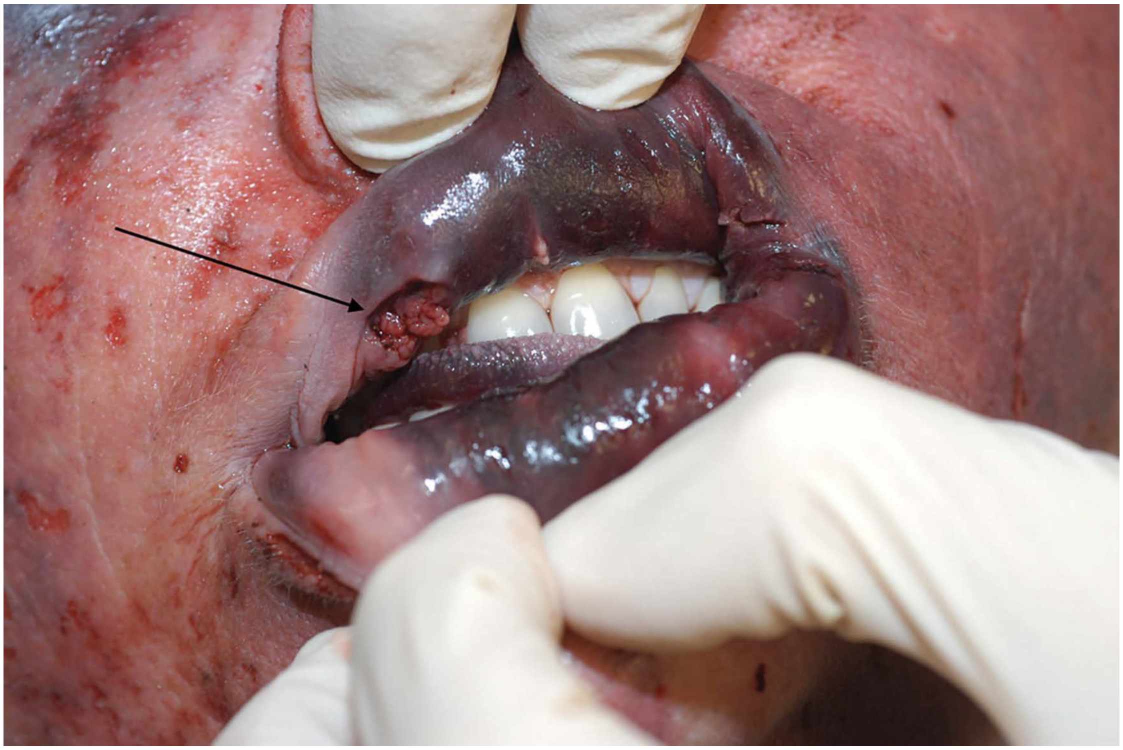


Figure 4.4 Laceration of lip due to underlying teeth. The configuration of a laceration is dependent on underlying bony structures. In this figure, the lip was lacerated as it became "sandwiched" between the fist that causes the contusion and laceration and the teeth below. A similar blow to a soft area, like the stomach, would likely not have caused a laceration.

Figure 4.5 (a) Usual abrasions. Abrasions are the pattern in the skin caused by a blunt object denuding skin. This victim of a motor vehicle crash shows usual abrasions on the knees, commonly known as "scrapes." **(b) Sliding abrasion.** This victim was thrown out of a moving vehicle. The long axis of the abrasions show the direction the body moved across the pavement.

Figure 4.6 Pressure abrasion. The shoulder shows a yellow indentation below a purplish thermal burn. This victim's shoulder was wedged in a roller mechanism, whose shear force crushed the shoulder. The pressure flattened and thinned the skin so that the fat beneath shows through. The mechanism was also hot, producing the thermal burn on the upper part of the shoulder.

Figure 4.7 Pattern abrasions. (a) This individual struck a solid object in his vehicle at a high rate of speed, causing this patterned abrasion of the leg. Automotive aficionados will recognize this as a General Motors-type brake pedal. Studying patterned abrasions can be useful in that they can leave an outline of the object that caused the injury. **(b)** The rope in this suicidal hanging shows a pattern abrasion of the rope braid. The weight of the body has also produced a pressure abrasion, making the skin thinned. The subcutaneous fat is showing through and there is a laceration of the skin at the margin. **(c)** The pattern of this broken handle is reflected in the pattern abrasion produced by striking the buttock skin.

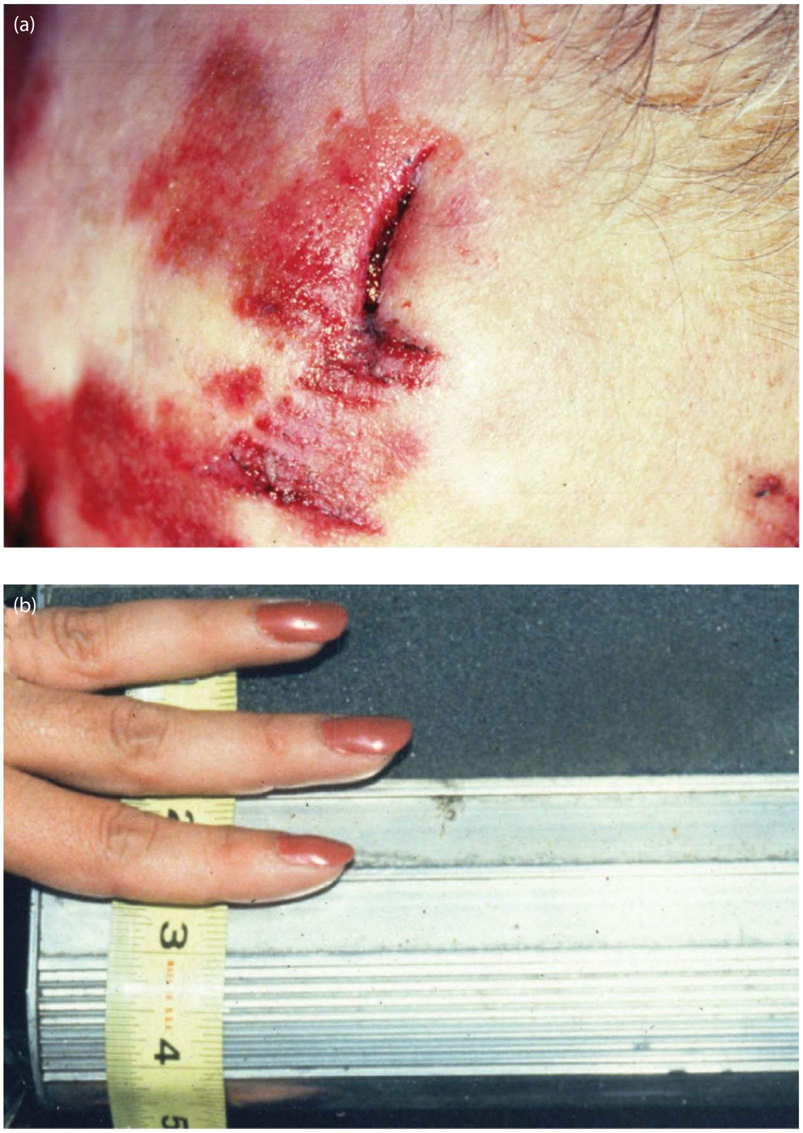


Figure 4.8 Pattern abrasion with a flanking contusion. Objects with complex surfaces often cause complex injuries. Regular, periodic, linear abrasions can be seen below the central laceration in **(a)**. One probable explanation for this patterned abrasion/laceration is that the head was propelled against the floorboard **(b)** of this truck found at the scene, since the ridges match up to the abrasions seen in the injury.

Figure 4.9 Contusion with cylindrical object. This contusion is on a living person who was thrown into the wire rigging of a sailboat. The central clearing of the contusion is where the wire struck the skin. The blood is "milked" and forced from the central area of contact to the periphery. The contusion is approximately 4 days old (by history) and a golden–brown hue can be seen in the center of the lesion (see text regarding healing contusions).

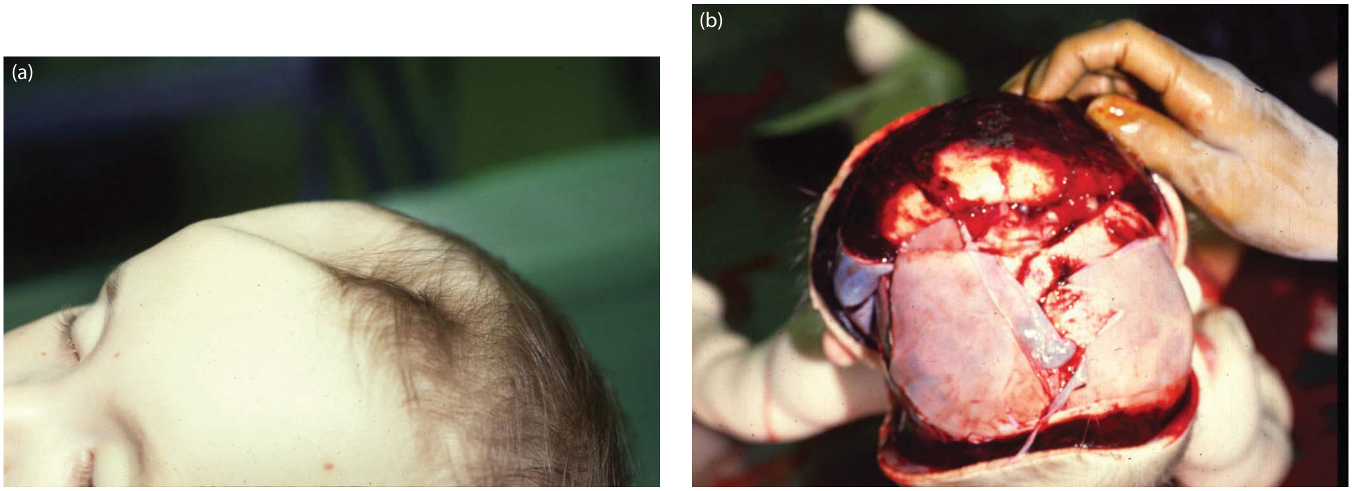


Figure 4.10 Depressed skull fracture with no visible contusion. A depressed skull fracture can be seen clearly in **(a)**, but no contusion is visible. When the scalp and galea aponeurotica is reflected back in **(b)**, extensive contusion hemorrhage can be seen. This illustrates the value of autopsies in children, since contusions can be hidden. The tissues of children are more opaque and elastic, tending to hide underlying hematomas.

Figure 4.11 Orbital ecchymoses or "raccoon eyes." The darkening of the soft tissue around the eyes is due to blood accumulating in the soft tissues. This finding alerts the pathologist to search for fractures in the base of the skull, most likely the frontal bone or orbital roofs.

Figure 4.12 (a and b) Patterned bumper contusion. This individual was killed by multiple strikes with an automobile. This figure shows two linear contusions of the knee, caused by the bumper striking the victim while walking. The height of these injuries can be measured on the body (with shoes if applicable) and compared to the bumper height of the vehicle. In addition, the configuration of the contusion can be compared to the bumper of the vehicle. Other tests can be performed on the vehicle, such as inspecting the vehicle bumper, tires, and undercarriage for blood and tissue. This material can be tested for DNA comparison to the victim. Tissue can be studied under the microscope to identify the body region of origin. **(b)** Patterned tire contusion with pressure abrasions. This victim was crushed by a vehicle that ran over him while lying supine (flat). The arrow shows a tire pattern. Pressure abrasions and crush injuries such as fractures can be seen.

Figure 4.13 Contusions of the neck. This individual was the victim of manual strangulation. Multiple contusions (and a few abrasions) are seen at the midline of the neck and the base of the jaw in particular.

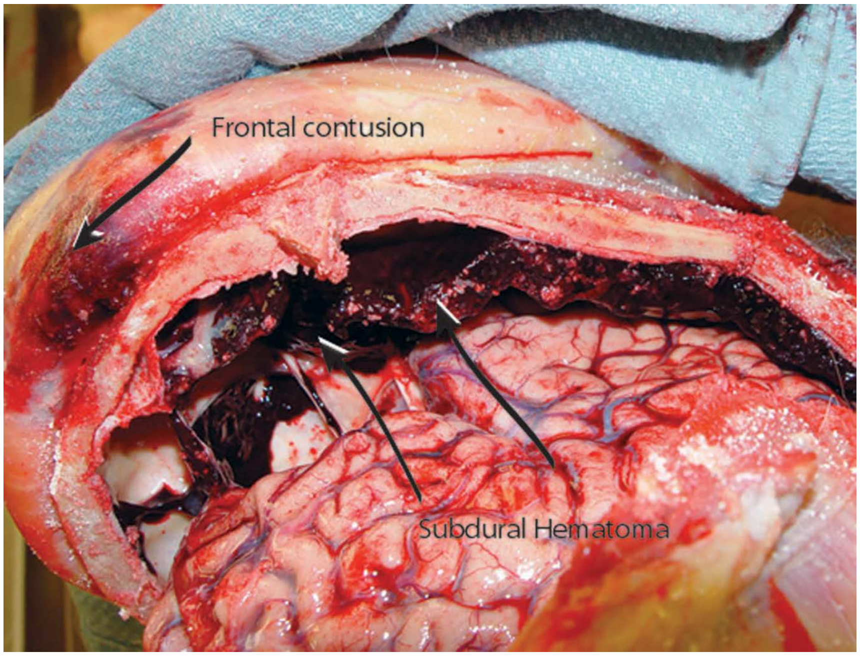


Figure 4.14 Subdural hematoma. A large hematoma can be seen between the brain and the dura, shown by the arrow. The pressure of the hematoma can affect the function of the brain, resulting in coma and death. This hematoma was produced by the decedent falling and striking his forehead. The small veins bridging the dura and the brain happened to be torn during the fall, resulting in hemorrhage.

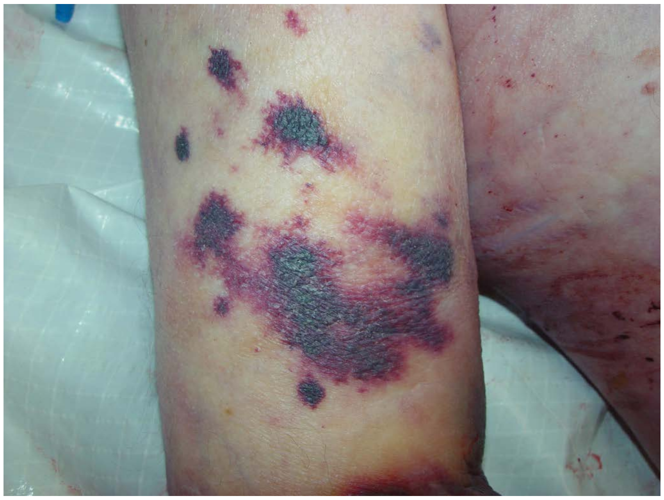


Figure 4.15 Ecchymoses. Ecchymoses are confluent, visible areas of hemorrhage under the skin. These lesions are commonly seen in the very ill or elderly, especially in patients with poor, thin skin or those taking blood thinners like Coumadin.

Figure 4.16 Conjunctival petechiae. Small, point-like hemorrhages in the conjunctiva, or clear membrane of the eye, are often seen in asphyxial deaths. These petechiae are due to hemorrhage of the small vessels in the conjunctiva, caused by the increased vascular pressure seen in asphyxia.

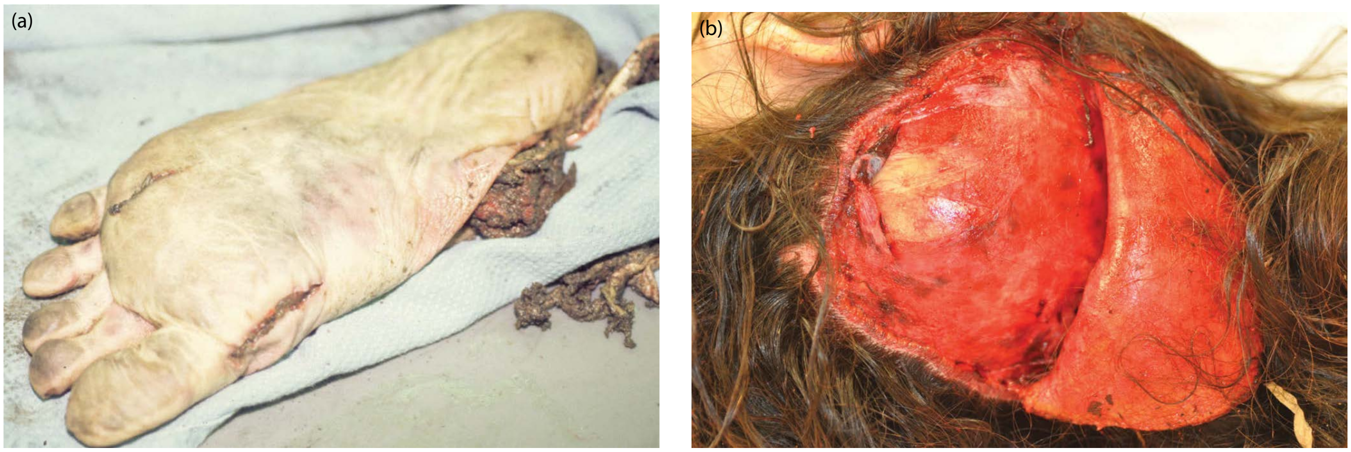


Figure 4.17 (a and b) Avulsions of tissue. Avulsion implies a forceful tearing of tissue or an entire body part away. Airplane crashes impart tremendous force to tissues, causing shearing and shredding of the entire body. Intact body parts can be difficult to find in high-speed airplane crashes. **(b)** Automobile crashes involve tremendous forces, particularly when the occupants are ejected, as in this case where the scalp shows an avulsion. Wearing a seat belt virtually prevents ejection from the vehicle.

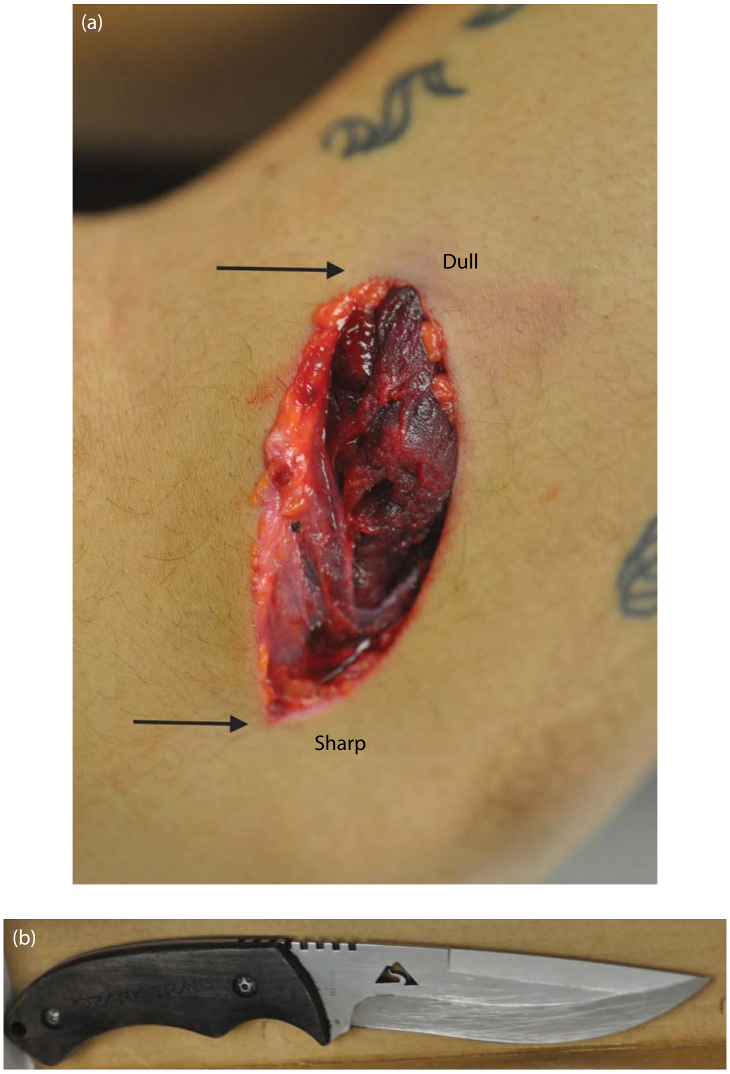


Figure 4.18 Stab wound produced by a single-edged knife. (a) The knife is sharp on the "edged" part of the knife. The opposite side of the knife is dull. **(b)** The sharp and dull edges can produce different marks on the wound edge.

Figure 4.19 Stab wound with hilt mark. Stab wounds are deeper than they are long. This stab wound demonstrates that the full length of the knife was thrust into the body. The abrasion on the wound and the radial marks surrounding the wound were caused by the hilt, or end, of the knife. The two outside abrasions were caused by the finger guards of the knife. These characteristic marks could be used to exclude or include unknown knives in an investigation.

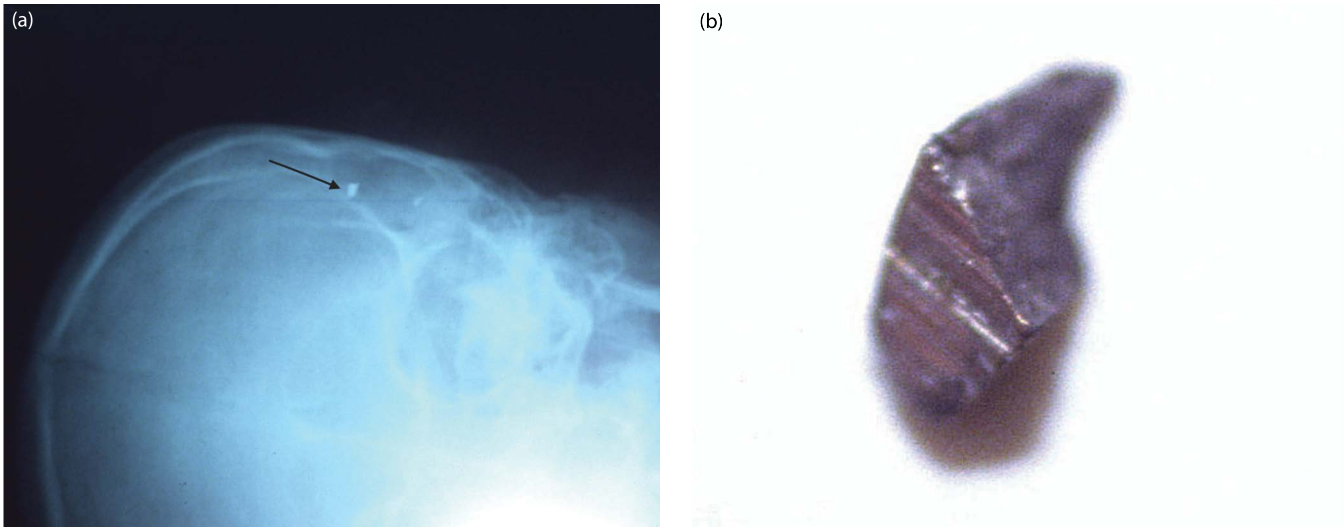


Figure 4.20 Scissor fragment in skull. Radiographs are not only for gunshot wounds. **(a)** In this x-ray of a stabbing victim, a small metallic fragment can be seen in the middle of the figure as a white dot near the top. This victim was stabbed with a scissors, part of which broke off in the skull. The small fragment was removed at the autopsy. **(b)** Knife tips can break off when hitting bone as well. The broken fragment can be matched to a purported weapon.

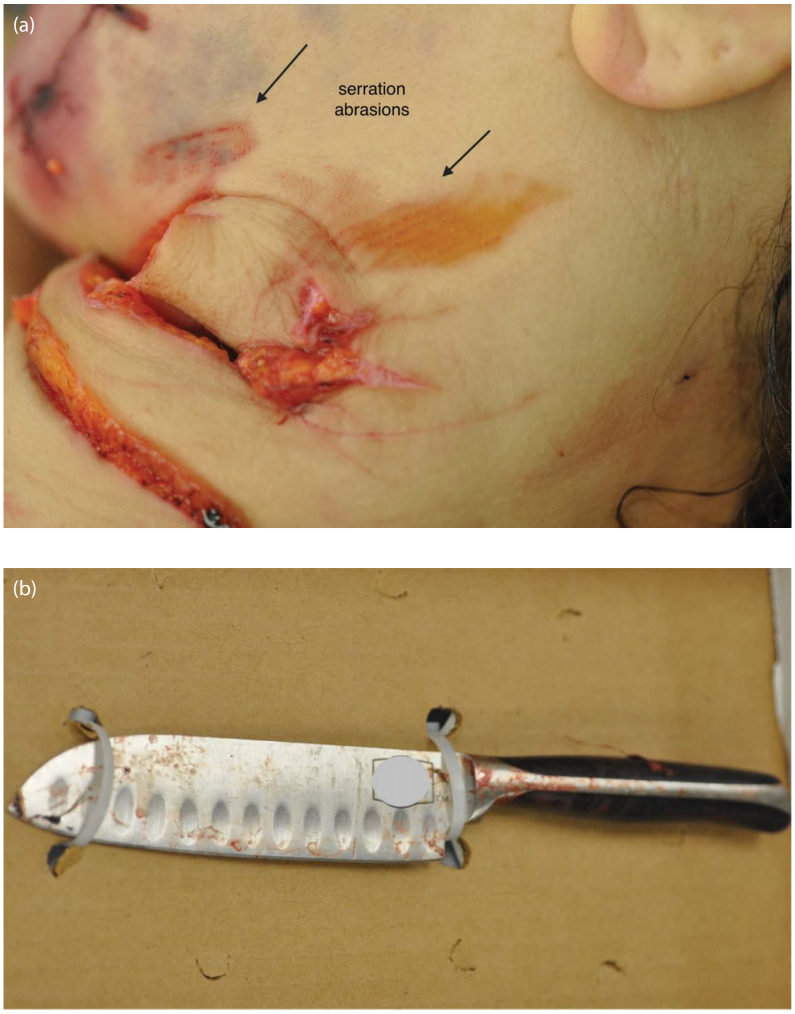


Figure 4.21 Sharp force injuries from cutting or hacking. (a) Hacking injuries are sharp force injuries that are produced from cutting the skin and soft tissue back and forth. These are often abrasions on the margins of the wound, which in this case **(b)** suggest that this bloody, partially serrated knife found at the scene has a pattern that is consistent with some of the injuries.

Figure 4.22 Incised wounds of the wrist (hesitation cuts). Incised wounds are longer than they are deep. These characteristic incised wounds of the wrist, seen in suicide attempts, are also called hesitation cuts.

Figure 4.23 Incised wounds of the hand (defense cuts). Defense cuts are a special type of an incised wound encountered when the victim attempts to fight off a knife attack. The deep cuts seen here tell us the story of the violence inherent in the attack and the determination of the victim to prevent the attack.

Figure 4.24 Puncture wounds of the chest. The victim was killed with an ice pick. The multiple stab wounds are located around the heart. The purposeful placement of the ice pick wounds around the heart displays the determination of the perpetrator (i.e., these are not randomly placed puncture wounds).

Figure 4.25 Chopping injuries: axe and axe wounds. Axes, swords, machetes, and other such weapons have sharp edges and weight. **(a)** These weapons can cut, tear, and break bones. The cuts are often long and deep **(b)**. An axe can cause blunt force injuries and sharp force injuries. The wrist wound depicted here shows abraded margins such as a laceration. **(c)** The weight of the axe in this victim has not only cut the tissue, but has caused fracture-comminution of the skull.

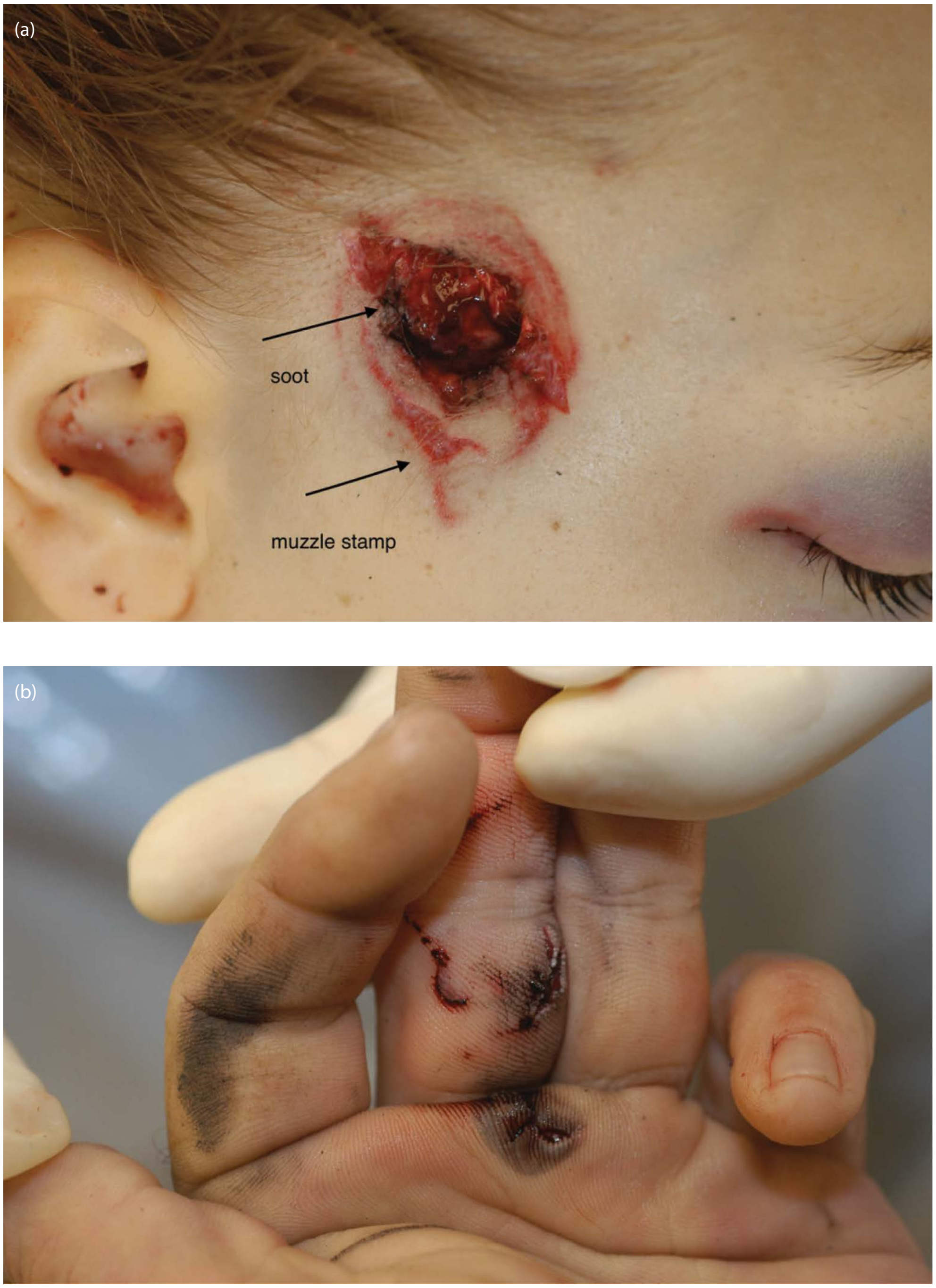


Figure 4.26 Gunshot wounds in suicide. The gunshot wound in **(a)** shows a typical hard contact gunshot wound of the right temple in a right-handed person. At 7 o'clock, there is an abrasion from the sight of the pistol. The wound in **(b)** shows lacerations and soot deposition where the pistol slide caught the skin of the hand. This is supporting evidence that the decedent fired the pistol. All gunshot wound cases, suicides included, should undergo a complete death investigation, including an autopsy.

Figure 4.27 Pistol found in decedent's clothing. (a) As part of the external examination, this loaded pistol was found in the pocket. **(b and c)** The semi-automatic pistol has a magazine that fits into the base of the grip. One must remember that a loaded pistol with the magazine in place will likely have a round in the chamber, which can only be removed by pulling the slide back (or by firing the pistol!). Some pistols will fire with the magazine removed. Please remember that a loaded or suspicious firearm should only be handled by experienced personnel.

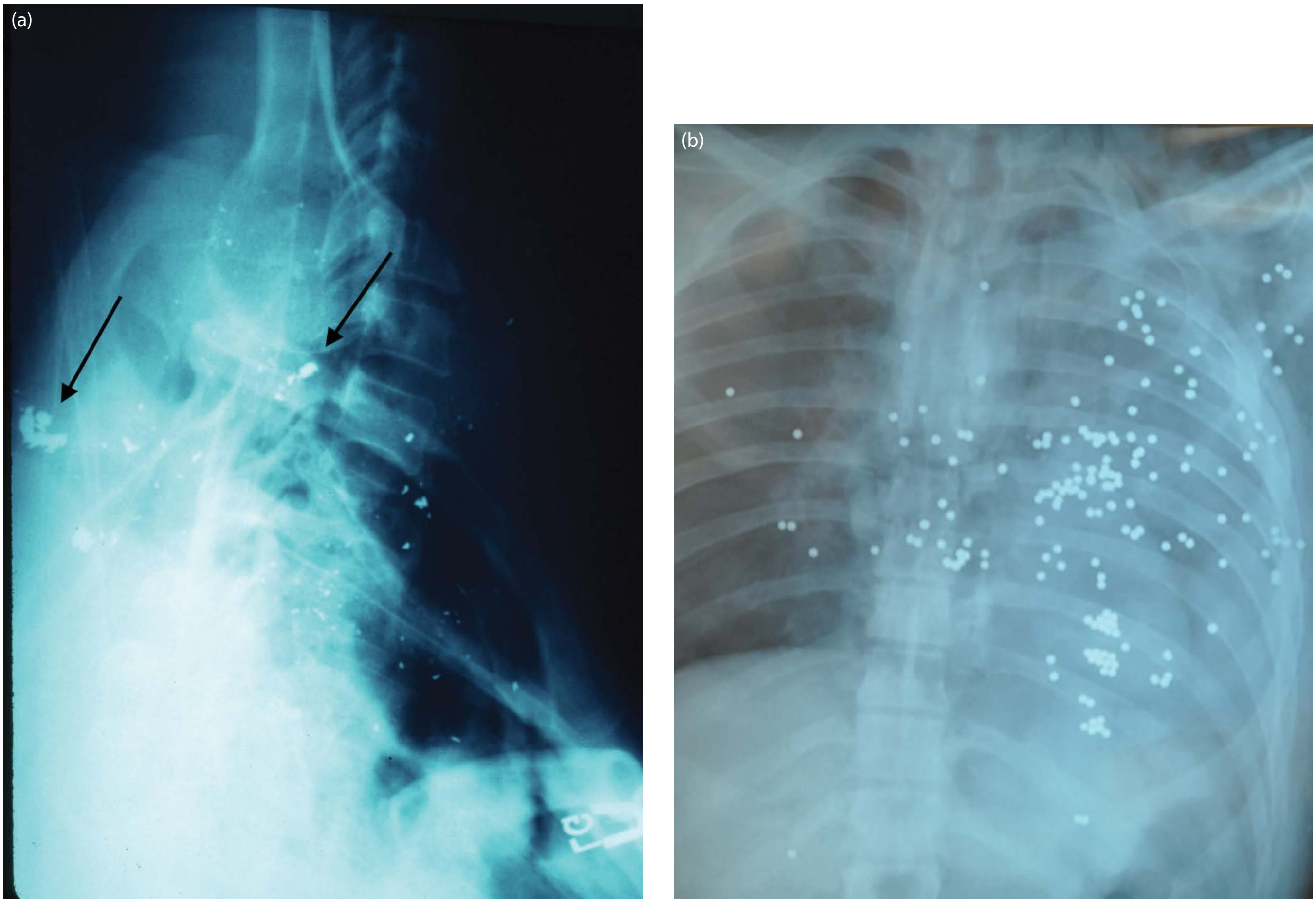


Figure 4.28 X-rays of high-powered rifle (a) and shotgun wounds (b). This lateral film of the neck shows metallic flakes in a complete path through the neck area **(a)**. This person was shot with a high-powered rifle. **(b)** Multiple shot or "BBs" can be seen in this shotgun wound. The pathologist explores the wound to look for shot, wadding, paper discs, and shot cup to further characterize the wound.

Figure 4.29 Bullet removed at autopsy. The bullet is removed by the pathologist, photographed (or the base is marked by some pathologists), and handed off to the crime scene investigator. The bullet is cataloged by the location in which it was found in the body. The forensic pathologist does not determine caliber, as that is the purview of the firearms examiner ("ballistics expert").

Figure 4.30 Hard contact entrance gunshot wound. (a) The patterned abrasion at 10 o'clock and the red abrasion ring around the wound were produced by the gun barrel and sight contacting the skin when the gun was fired. The black material around the wound is heavy soot. The finding of a hard contact wound on the chest of this individual, along with a complete death investigation, supports the theory of suicide. **(b)** A hard contact gunshot wound is shown, as produced by a .22 caliber rifle **(c)**, which has produced an imprint of the site at 12 o'clock.

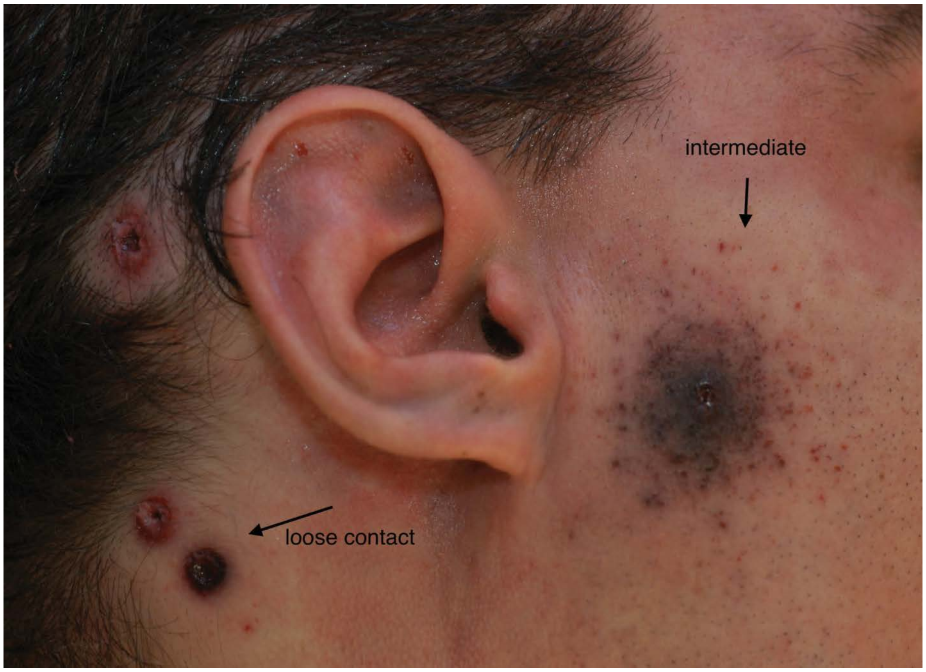


Figure 4.31 Loose contact gunshot wound. The gunshot wound in the lower left-hand corner of the photo shows surrounding soot. The gun muzzle was held slightly away from the skin, causing soot to go into and around the wound. The wound in front of the ear shows a soot pattern that is wider and begins to break up, causing stippling, otherwise known as an intermediate-range wound. The other two wounds behind and below the ear show no soot or stippling, so the range is classified as "undetermined" for these two wounds.

Figure 4.32 Near-contact gunshot wound. This term is used by some authors to describe a pattern that is between a contact and intermediate-range gunshot wound. A wide rim of soot surrounds the wound since the barrel is not touching the skin, and is likely to have been less than 1 inch away. If stippling is seen, the wound must be classified as an intermediate gunshot wound.

Figure 4.33 Intermediate-range gunshot wound. Any gunshot wound with stippling (small dots surrounding the wound) is referred to as an intermediate-range gunshot wound. **(a–d)** Stippling produced from a gun barrel that is closer **(a)** to progressively farther away **(b–d)**. Note how the pattern is more dispersed the farther the barrel is away from the skin. Unburned portions of gunpowder tattoo the skin; therefore, the stippling marks cannot be washed off. The stippling must be measured in all directions. The firearms examiner can then fire test patterns with the same gun and ammunition at known distances. These patterns can be compared to the unknown pattern on the body, and so the distance can be estimated. See text for a description of this.

Figure 4.34 Undetermined-range entrance gunshot wound. This gunshot wound has no surrounding soot or stippling; therefore, the range cannot be determined. The wound shows a round to oval abrasion, characteristic of an entrance wound.

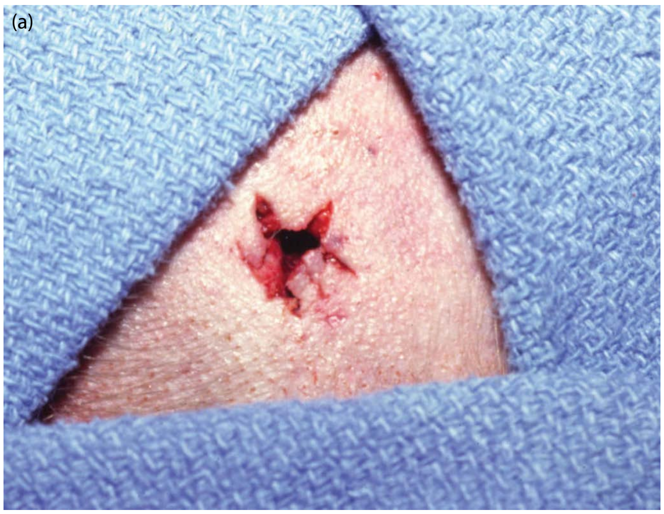


Figure 4.35 Exit wound. (a) This exit wound is stellate in configuration. No soot or abrasion can be seen around the exit wound, caused by a .22 caliber bullet. **(b)** This exit wound on the hand had more of an oval shape. Exit wounds can display many shapes and sizes and can resemble entrance wounds. For this reason, classification of gunshot wounds as exit or entrance wounds should only be made after a complete autopsy.

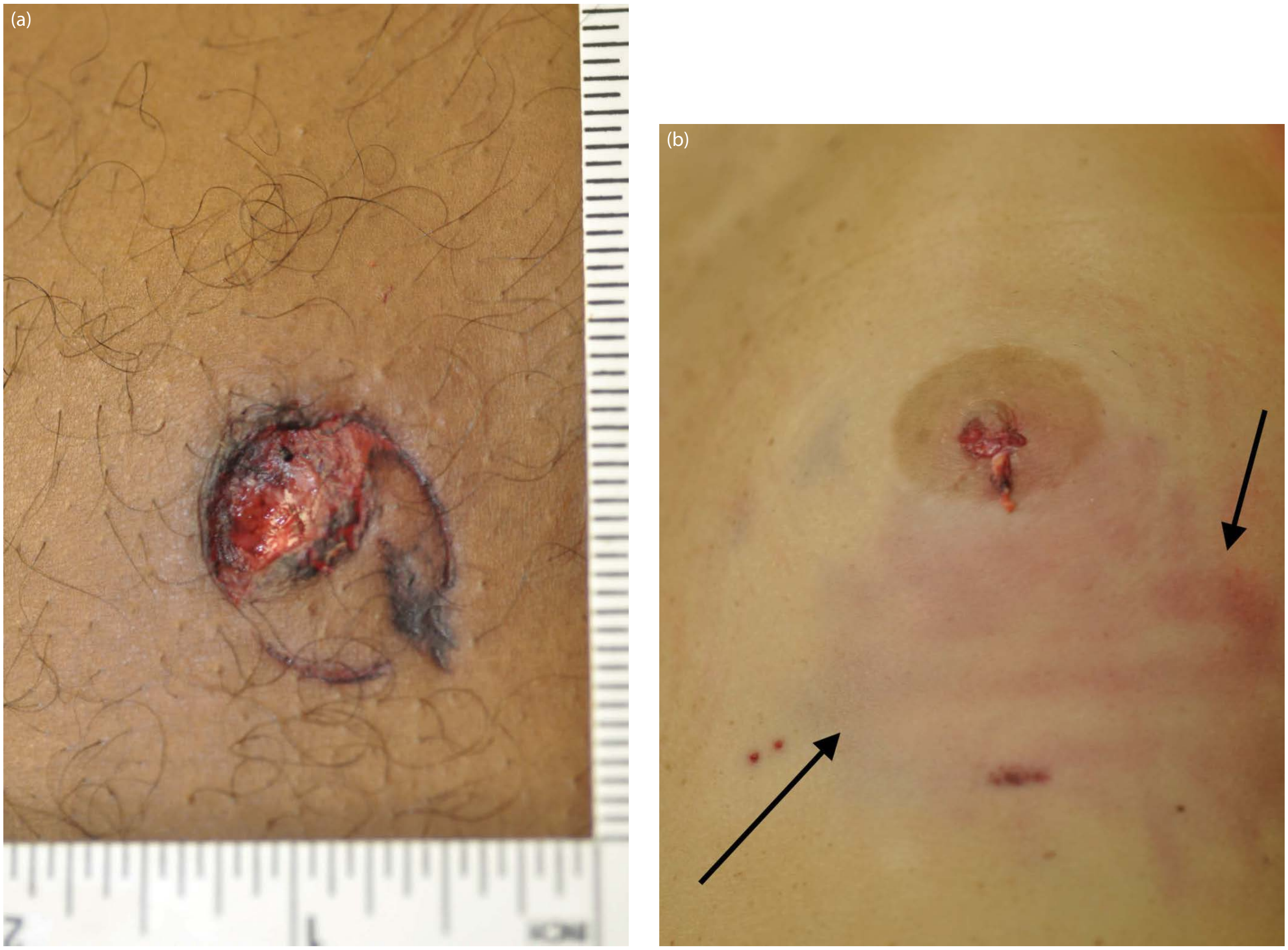


Figure 4.36 Shored exit and entrance wounds. (a) The bullet struck a medallion on the victim's neck, producing this circular abrasion. When the bullet is exiting the skin, objects next to the skin in the region of the wound track can strike the skin and cause a secondary wound, called a shored exit wound. Common objects producing this effect include a wall or floor, leather or very thick coats, belts, bras, wallets, and jewelry. **(b)** This entrance gunshot wound of the nipple shows a contusion and abrasions below the breast, due to an underwire bra being stretched and slapping the skin.

Figure 4.37 Graze wound. As the wound tangentially contacts the skin, it is abraded and torn. The tears point to the direction that the bullet travelled over the skin.

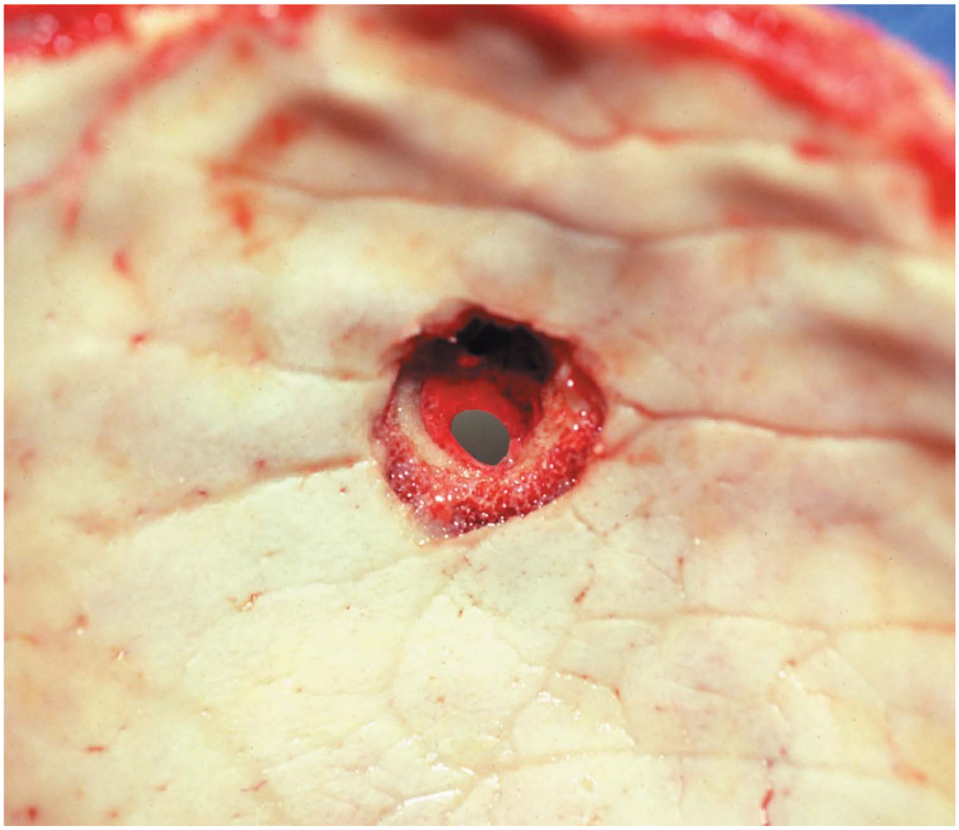


Figure 4.38 Entrance wound of the skull. The convexity of the skull is a thick bone that can produce a special type of wound in which the direction can be confirmed by examining the bone. To produce this wound, the bullet path must be from behind the page, toward the reader. The bullet cores out a wedge of bone in front of it as it travels. The pointed end of the wedge is at the point of entry, and the base is produced as the bullet exits the skull.

Figure 4.39 Intermediate target in a gunshot wound. This person was shot while holding up a blanket. The filling of the blanket was carried into the gunshot wound.

Figure 4.40 Shotgun wound. (a) Shotgun shells contain multiple small "BBs," called shot. As the shot comes out of the barrel of the gun, it stays together for several feet, then starts to separate. As this individual shot breaks up and hit the skin, characteristic individual satellite shot injuries can be seen around the main hole. The wadding was found in the wound. **(b)** This image shows a hand as an intervening target in a shotgun used in a suicide. Black soot can be seen on the hand, as it was closer to the barrel. Again, the wadding was found in the wound. **(c)** This image shows a distant shotgun wound produced by 00 buckshot. **(d)** This is a loose contact shotgun wound. **(e)** This image shows the slug and wadding recovered from the wound in **(d)**.

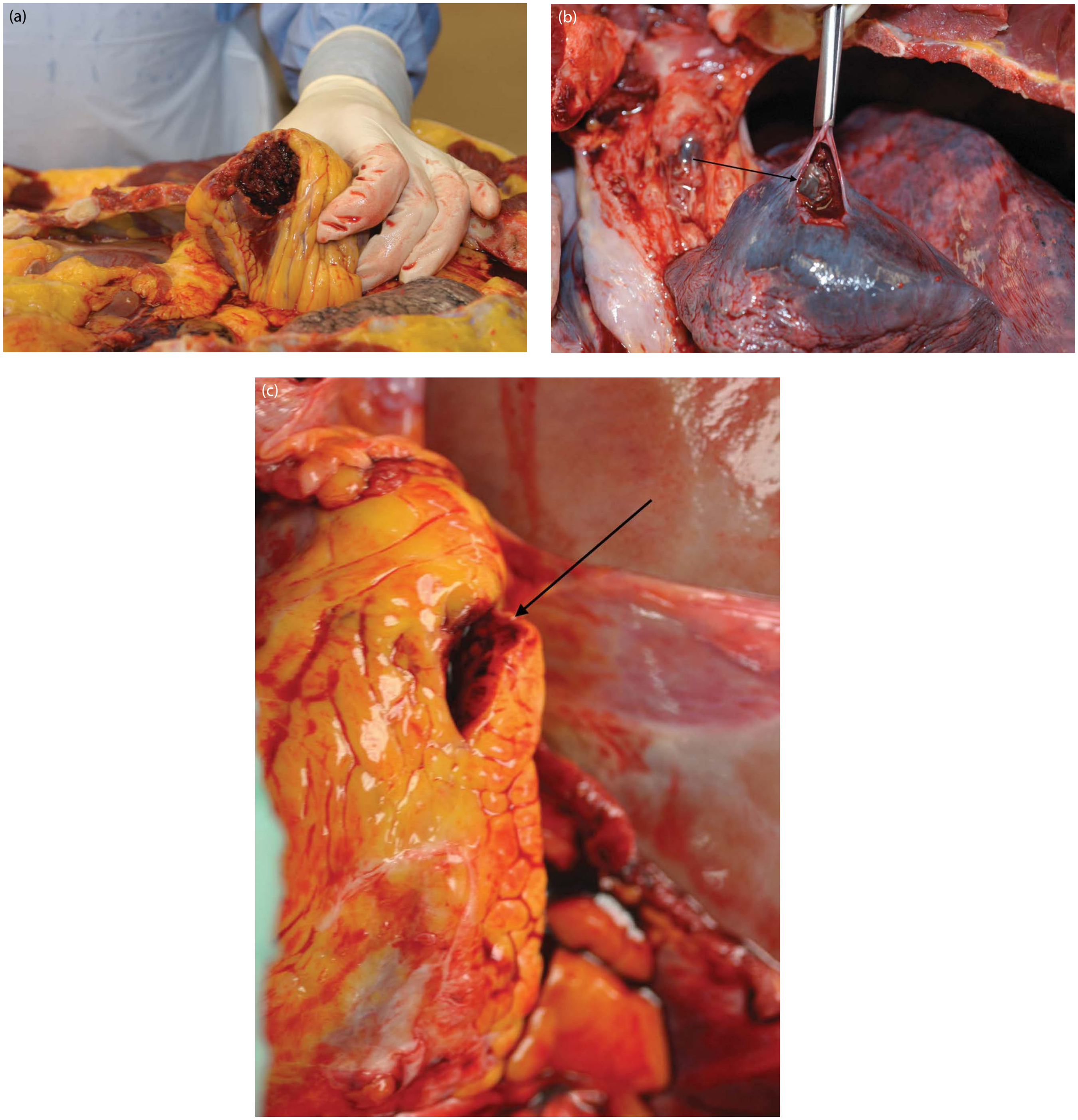


Figure 4.41 Wound tracks through individual organs. Starting with the skin wound, the wound track is followed through the body. Wounds going through vital organs are those that are most likely to produce death, with exsanguination being the most common mechanism of death, as in the heart **(a)**. Wounding of the lung **(b)** can cause hemorrhage and pneumothorax, collapsing the lung so that oxygen cannot be taken into the lung. A bullet was found in this lung. **(c)** This image shows a stab wound track from a knife, involving the heart.

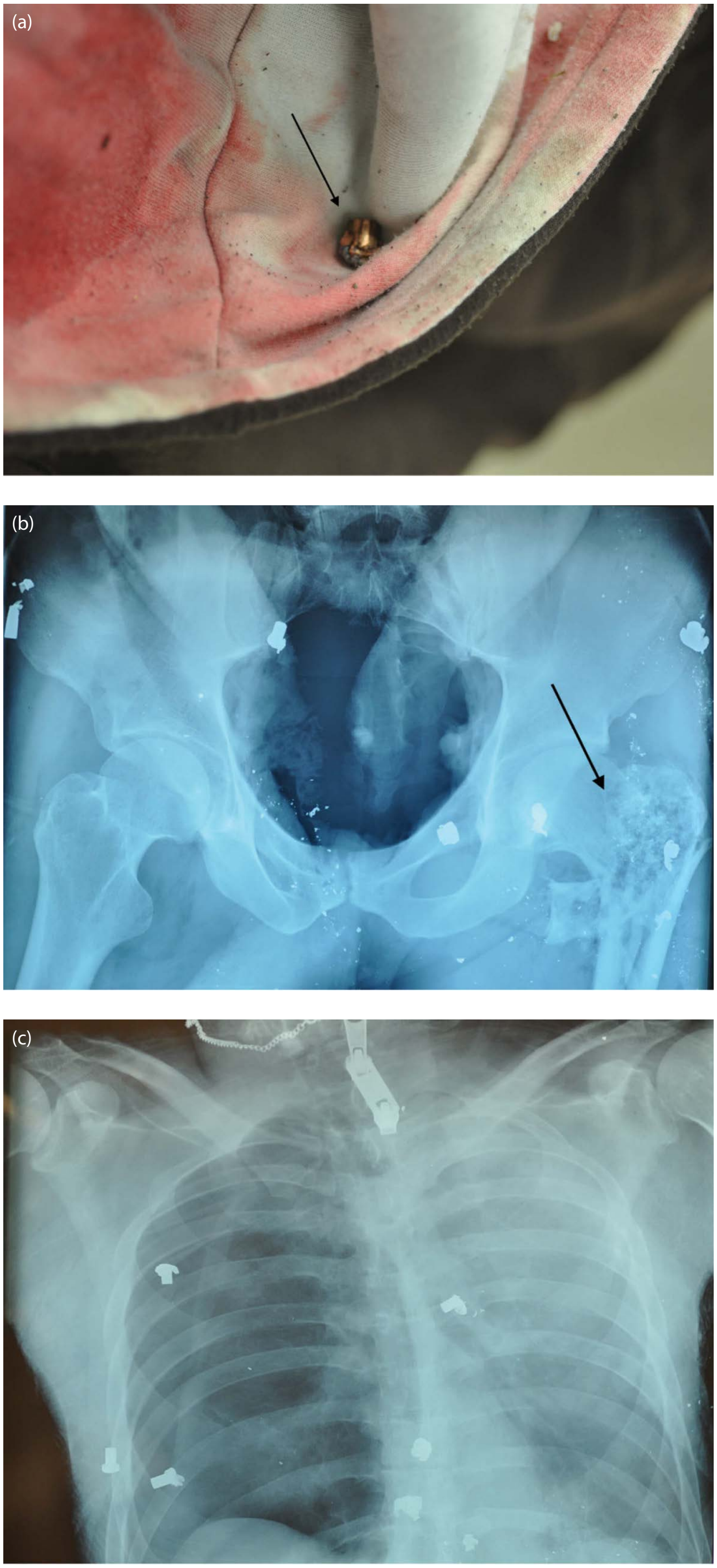


Figure 4.42 Bullet in clothing. (a) Some articles of clothing can trap bullets. A bullet was found in the hood of a sweatshirt. For this reason, the clothing should be x-rayed and carefully searched, so as not to lose a bullet or other trace evidence. **(b and c)** X-rays of the pelvis and chest show multiple bullets. The x-rays help with locating the bullets and documenting deep injuries, such as fractures. The arrow in **(b)** points to a hip fracture produced by the gunshot wound.

Figure 4.43 (a and b) Cartridge casing and bullet jacket in the hair and clothing. The hair should be examined carefully for evidence. As shown here, a missing cartridge casing was found, and at approximately 8 o'clock (arrow on left), a bullet jacket can be seen in the clothing.

CHAPTER 5

EXTERNAL EXAMINATION: SPECIFIC BODY AREAS

OVERALL PICTURE OR "GESTALT"

After the body has been undressed and carefully cleaned, the pathologist steps back from the body and looks at the overall position or shape of the body (habitus). Is the body symmetrical? Is there morbid obesity, or is the frame extremely thin (indicative of cachexia)? Is there an overall deformity? For example, is the body in a fetal position? Is there something amiss or out of place? This is also a good time for the pathologist to reflect on what has been done up until this point of the autopsy and what is about to be done.

SKIN

The skin is technically an organ *per se*. It is the organ that is most carefully assessed during the external examination. The skin acts as an outward sentinel or "red flag" for deep injuries or diseases within the body. The skin of the individual in Figure 5.1a shows a brown pigmentation in the axilla ("armpit"), a condition known as acanthosis nigricans. Also on the trunk are multiple brown, greasy-looking benign moles, known as seborrheic keratoses (Figure 5.1a and 5.1b). Observation of this number of lesions alerts the pathologist to look for an internal cancer, usually of the gastrointestinal tract. In fact, this unfortunate individual had carcinoma of the colon (Figure 5.1c). (See Video 5.1.)

HAIR

Hair color is noted for identification. Hair roots can be used for DNA identification; at least 50 hairs must be pulled, not cut, since the DNA is in the roots. Hair can contain trace evidence or gross evidence, such as the knife used to murder this individual (Figure 5.2a and 5.2b). Toxicologic analysis of hair is useful for diagnosing chronic drug use or poisoning. Since hair tells the story of what was going on in the body weeks or months before death, it is not useful for analysis of acute drug or poison toxicity.

SCALP

An injury of the scalp is often the sentinel to deeper injuries, like skull fractures, brain contusions, and hematomas. Hair can cover injuries, particularly those that do not bleed, so a careful examination must be undertaken. Small-caliber gunshot wounds are notoriously difficult to find in thick hair. Scalp injuries on the back of the head can be easily overlooked (Figure 5.3). In order to see a scalp wound and photograph it properly, the hair around the wound is carefully shaved (Figure 5.4). The wound in Figure 5.3 is a laceration with an abrasion of the margin. The skull below this area in the same individual revealed a fracture in the back of the head, or occipital bone (Figure 5.5). The opposite part of the brain, or frontal lobe, shows contusions, indicating that the person fell backward and was not struck in the head. Figure 5.6 shows that this is a contrecoup injury.

FACE

The face is dissected only in rare cases (e.g., to retrieve a bullet or other evidence). Every attempt should be made not to cut or alter the face, both out of respect for the individual and in consideration of viewing at the funeral service.

Facial injuries can be important in determining who was driving when multiple individuals, usually unbelted, die in a motor vehicle crash. Identifying the driver can be important if the vehicle was operated unlawfully (e.g., the driver was under the influence of alcohol). Automotive side glass is tempered, not laminated like the windshield. When it breaks, automotive side glass shatters into many small cubes that tend to cause small cubic cuts and abrasions on the face. Hence, the driver tends to have side glass injuries on the left side of the face. These injuries, as always, do not prove who was the driver or passenger and must be looked at in the context of the entire case (Figure 5.7).

EYES

The eye (iris) color is recorded, and the eyes are examined for hemorrhage. Small punctuate (point-like) hemorrhages in the conjunctiva (white part of the eye) often suggest an asphyxial cause of death (Figure 5.8). Yellow conjunctiva

(jaundice) might indicate liver disease or hemolysis, a disorder of many different causes in which the blood cells are broken apart in the body. The soft tissues around the eye (orbit) are very vascular. Blunt force to the area can easily cause contusion (a "black eye") relative to many other areas of the body. Orbital soft tissue hemorrhage can also be seen in skull fractures involving the base of the frontal bone in particular (Figure 5.9). This point illustrates the aim of the external examination: the outward hemorrhage directs the pathologist to look inward for a cause.

NOSE

The nasal cartilage can be fractured in traumatic injuries; therefore, palpation and increased range of motion can indicate fracture. Drug residues can be seen in the nares. The chronic snorting of drugs can damage the nasal mucosa.

MOUTH

The mouth can be tightly clenched due to rigor mortis. In such cases, it is difficult to open. Examination of the mouth after rigor is released is much easier. The teeth are examined, and visible teeth are cataloged (Figure 5.10a). Unusual teeth or dental appliances can be used to make an identification. Dental caries (cavities) are noted. Drug residue may be seen, such as in cases of drug abuse or overdose. In sexual assault cases, oral examination and swabs are taken to look for spermatozoa. In suffocation and strangulation cases, there are often injuries in the mouth (Figure 5.10b). These injuries can occur when the perpetrator forcibly holds the mouth closed.

NECK

The skin of the anterior neck is examined for contusions or abrasions that might suggest manual or ligature strangulation (Figure 5.11a). The thyroid gland is palpated in the lower lateral neck (Figure 5.11b). The neck is manually examined for tumor masses and enlarged lymph nodes (Figure 5.11c). The neck's range of motion is checked. A highly flexible range of motion is abnormal during rigor mortis, and reminds the pathologist to look for a fracture during internal examination.

CHEST

The chest is examined for symmetry and size (Figure 5.12a). Patients with emphysema and other chronic diseases often have an expanded, or "barrel" chest. Crepitus, or a crackling sound, indicates subcutaneous air from a pneumothorax. Rib fractures can be palpated as well. In severe chest injuries, such as from a high-speed motor vehicle crash, the chest can appear collapsed (Figure 5.12b).

BREASTS

The skin and nipple are observed for masses and ulcerations. The breast is palpated for masses and tumors (Figure 5.13a–d). The axilla, or armpit, is examined for enlarged lymph nodes. Breast cancers commonly spread to these axillary lymph nodes.

ABDOMEN

The abdomen is visually examined for distention, or bloating. Victims who have had cardiopulmonary resuscitation often have distention in the epigastric area. This is a result of air going into the stomach. The abdomen can also become distended (Figure 5.14a) due to hemorrhage or ascites (Figure 5.14b). Ascites is the accumulation of fluid in the abdomen, occurring in conditions like cirrhosis of the liver. Distention can also be seen due to bowel rupture and extensive inflammation, alerting the pathologist to take microbiologic cultures when opening the abdomen.

The abdomen is a common place for scars. The pathologist should search for scars including gallbladder, appendectomy, and other surgical scars. The presence or absence of scars can be helpful in identifying an individual.

EXTREMITIES, HANDS, FINGERS, AND NAILS

The pathologist must focus on the extremities, hands, fingers, and nails. These areas are easily forgotten, probably because their examination rarely elicits the cause of death. However, these areas are often rich in trace evidence and in clues to the cause and manner of death. For example, the extremities bear the brunt of knife attacks. Victims often grab the knife and hold their hands in a defensive position to ward off the attack. These wounds are often referred to as defense wounds (Figure 5.15a). The hands, nails, and fingers can carry trace evidence from a weapon or a perpetrator, such as wood fragments, hair, and skin. For this reason, the hands must be carefully examined and the fingernails scraped. Careful examination could show a portion of a missing nail. The death scene could then be searched for this torn nail fragment (Figure 5.15b).

Clues to natural disease processes can be seen in the hands and fingers. In Figure 5.15c, splinter hemorrhages in the fingernail beds are an outer sign of vegetations on the aortic valve, a condition called bacterial endocarditis. In

this condition, bacteria-laden thrombi break off from the valve and travel in the arterial system to the ends of the fingers and, more ominously, to the brain (Figure 5.15d), causing an abscess.

BACK

Since bodies are not easy to turn over, examination of the back is sometimes overlooked. In order to prevent this, the back is examined ritualistically at the same point in every autopsy. The back is a large area covering the back of the chest, the back of the abdomen, and even the posterior portions of the neck and abdomen. If many or key injuries are seen while the body is in the supine position, the body is carefully turned prone (face down) for documentation and examination of these injuries. Occasionally, the anterior, or front portion, of the body is free of injuries, while the back contains a serious injury (Figure 5.16a and 5.16b).

GENITALIA

The male genitalia are assessed for evidence of circumcision. This observation can be helpful in identification. The testes are assessed for tumors. Rarely, an undescended testis is noted. Injuries such as abrasions or bite marks may be seen in a sexual assault. If the penis has been traumatically severed, the resultant blood loss can be fatal.

The female genitalia are examined for tumors or developmental anomalies. In unnatural deaths, the female genitalia are examined for injuries from sexual assault. The sexual assault protocol includes an initial external examination for trace evidence such as hair. The vaginal area and rectum are examined for injuries (Figure 5.17a). The vagina, rectum, and surrounding areas are swabbed for semen or other secretions. The underpants and clothing are collected. The author has found commercially available sexual assault kits to be convenient since they contain more than enough material for conducting the examination (Figure 5.17b).

RECTUM/ANUS

Like the genitalia, the anus of both sexes is examined for sexual assault. Tumors and ulcerations are common findings in this region. In the bedridden, the sacral region, buttocks, and lateral ankles should be examined for pressure sores. The presence of such injuries might indicate elder abuse. Inflammatory bowel diseases, such as Crohn's disease, can be seen from inspecting the anus (Figure 5.18).

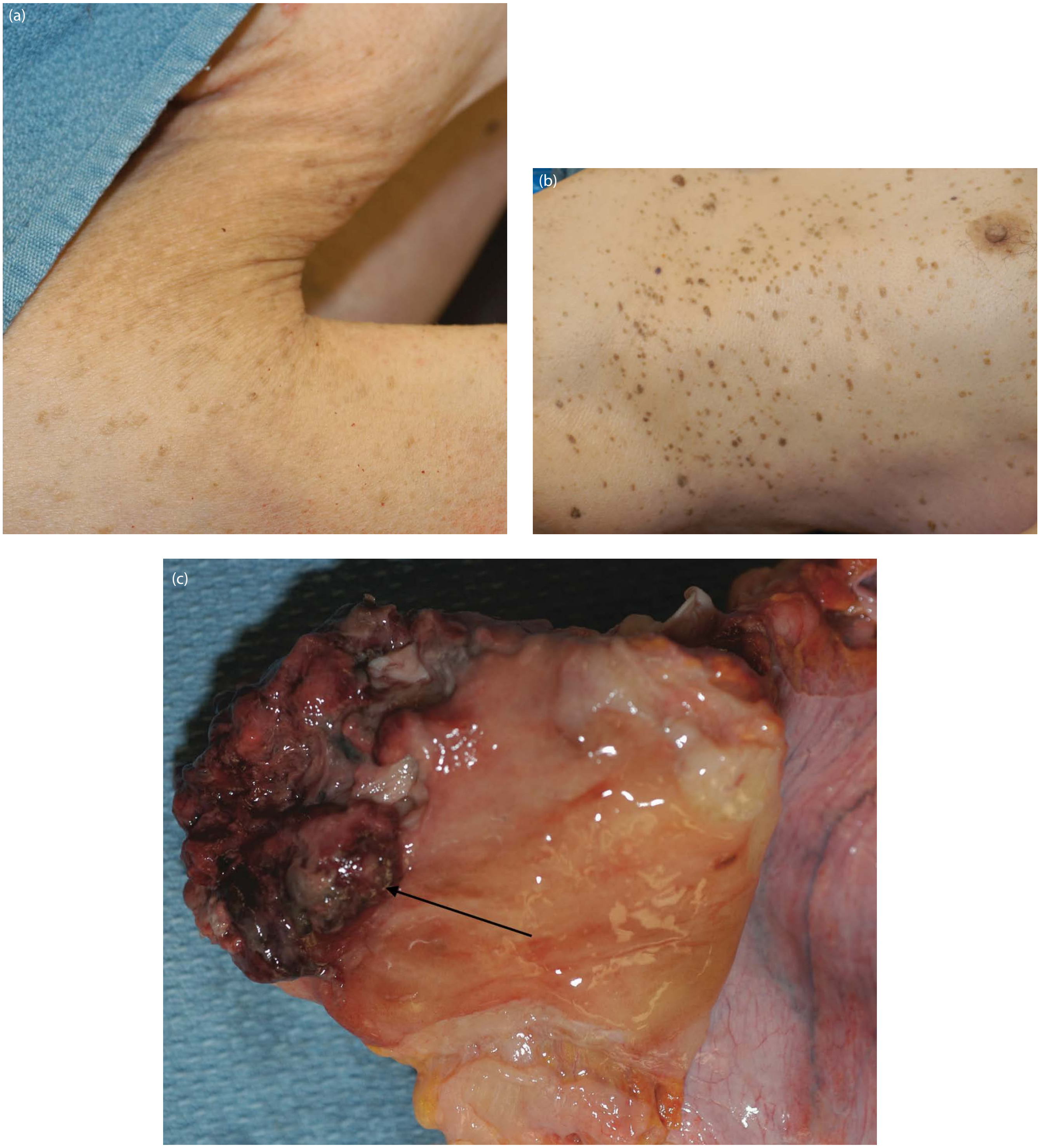


Figure 5.1 (a) Acanthosis nigricans. (b) Seborrheic keratoses. (c) Carcinoma of the colon. Dark pigmentation of the skin and multiple "greasy" keratoses on the body alert the pathologist to look internally for a visceral cancer. In the rectal–sigmoid colon of this patient, a carcinoma was found.

Figure 5.2 Broken knife found in the hair. (a) The hair must be carefully examined for evidence. **(b)** The murder weapon, a broken kitchen knife, was found in the hair of this victim.

Figure 5.3 Laceration of the scalp. The blood has been washed out of the hair, exposing what appears to be a laceration. One cannot be sure of this until the hair around the wound is shaved and the wound more closely examined (see Figure 5.4).

Figure 5.4 Close-up of laceration of the scalp. The hair around the wound has been shaved and the wound more carefully cleaned. One can see marginal abrasion, undermined margins, and tissue bridging. These findings, now clearly seen, demonstrate a laceration.

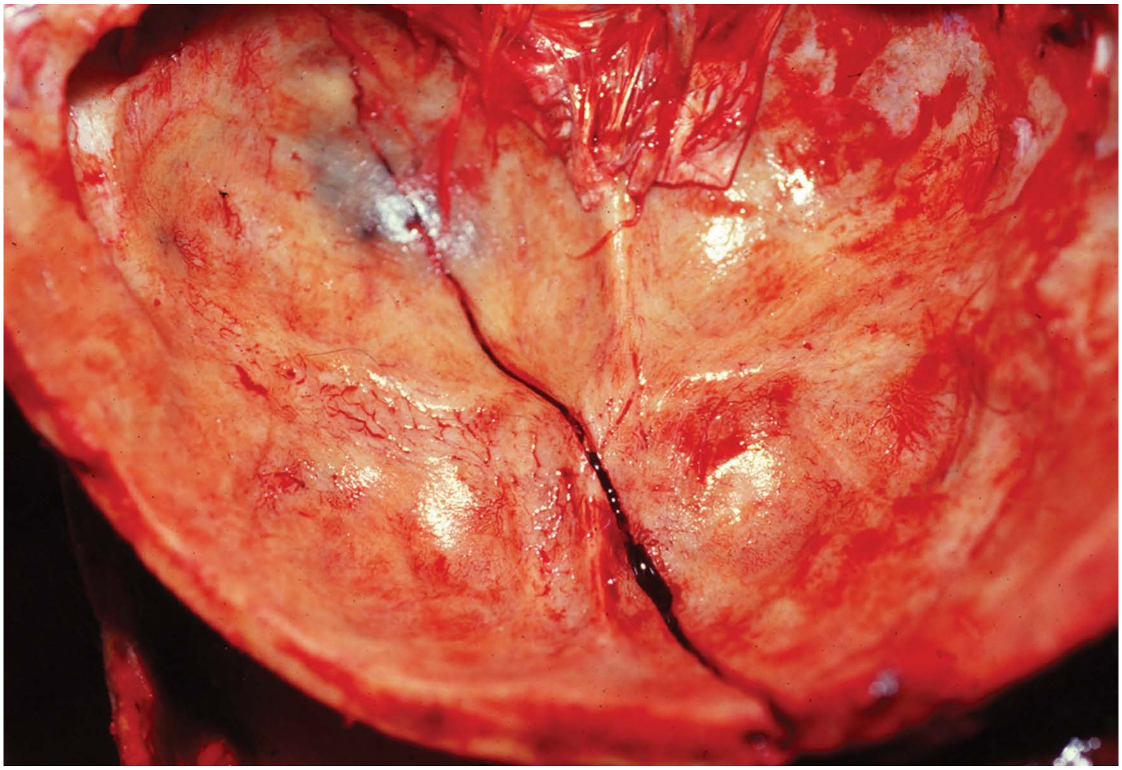


Figure 5.5 Fracture of the occipital bone of the skull. This fracture was discovered below the laceration shown in Figures 5.3 and 5.4. One must conclude that this is a blunt force injury. The question remains: was this person struck with a blunt force object or was there a fall (see Figure 5.6)?

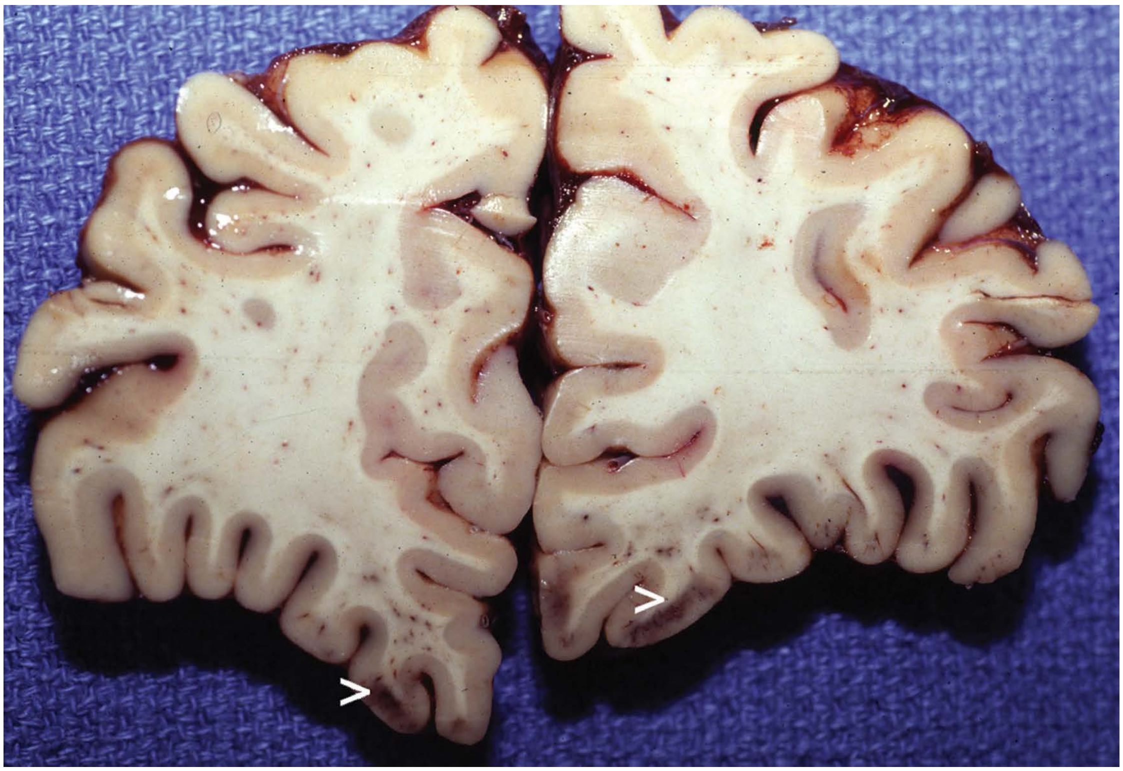


Figure 5.6 Contrecoup injury in the frontal lobe. Contusion hemorrhages can be seen at the arrowheads, near the bottom of the specimen. Their positioning indicates a contrecoup injury, meaning that the victim fell backward, striking and fracturing the occipital bone. The brain is moveable inside the skull; when the skull is impacted, the moving brain can slap against the frontal skull base, producing contusion hemorrhages such as these.

Figure 5.7 Side glass abrasions/lacerations. The face examination can be helpful in determining the driver in a motor vehicle crash. Since side glass is tempered, not laminated like windshield glass, it breaks up into small cubes upon impact, dicing the face. Often, but not always, injuries on the left side of the face indicate the driver, and those on the right side of the face indicate a passenger.

Figure 5.8 Conjunctival petechiae. Small, point-like hemorrhages in the conjunctiva, or clear membrane of the eye, are often seen in asphyxial deaths. These petechiae are due to the hemorrhage of small vessels in the conjunctiva, caused by the increased vascular pressure associated with asphyxia.

Figure 5.9 Orbital ecchymoses or "raccoon eyes." The darkening of the soft tissue around the eyes is due to blood accumulating in these soft tissues. This finding alerts the pathologist to search for fractures in the base of the skull, most likely the frontal bone or orbital roofs.

Figure 5.10 Examination of the mouth. (a) The mouth and teeth are examined for injuries and foreign material. The mouth is difficult to open in most autopsies because the jaw muscles are tightly clenched due to rigor mortis. **(b)** The upper lip shows contusion and abrasion in a victim who was strangled and suffocated. This injury was produced by external pressure on the mouth.

Figure 5.11 (a) Neck abrasions and contusions in strangulation. Multiple abrasions and contusions of the anterior neck are usually seen in strangulation injuries. In addition, searching for internal injuries of the neck is essential in order to opine that these injuries are due to strangulation. **(b and c) Examination of the neck.** The neck is palpated for masses, enlarged lymph nodes, and thyroid abnormalities. Tracheal deviation can indicate air in the chest or neck (pneumothorax and pneumomediastinum).

Figure 5.12 Examination of the chest. **(a)** The chest is examined for injuries, like rib fractures or crepitus due to air in the soft tissues. **(b)** The chest is flattened due to fracture of all the ribs anteriorly during a high-speed crash in excess of 100 mph; the airbag failed and the chest wall was crushed upon impact.

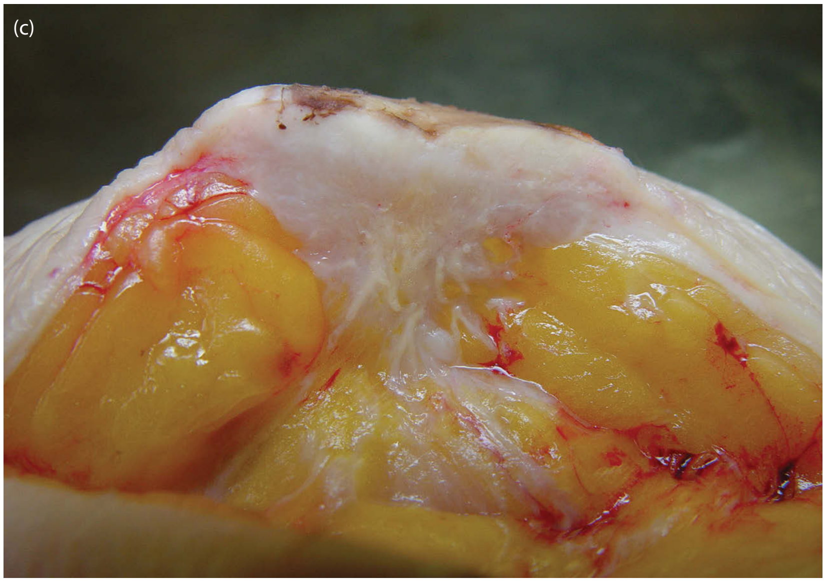


Figure 5.13 Breast examination, breast carcinoma, and supernumerary nipple. (a) The breasts are examined visually and by palpation for tumors and other deformities. **(b and c)** These surgical specimens show a large, ulcerating tumor of the nipple. The cut section demonstrates a white tumor in the midline infiltrating the surrounding skin and subcutaneous fat. **(d)** This image shows an extranumerary or supernumerary nipple. This is a remnant from embryonic development and is important in that carcinoma can arise here just as it can in the main breast.

Figure 5.14 Abdominal examination. (a) The abdomen is visually examined for distention and other abnormalities. The abdomen is palpated for solid masses and enlargement of the spleen and liver. **(b)** The patient died from carcinoma of the ovary. The extremely distended abdomen is the result of excessive fluid in the abdominal cavity.

Figure 5.15 Examination of the hands and fingers. Examination of the hands is useful in both forensic and medical cases. The hands usually must be opened for examination, since rigor mortis often causes them to clench. **(a)** This image shows defense cuts on the palmar surface of the hand, wounds that were obtained from defending against a knife attack. **(b)** This image depicts a finger and broken nail from a homicide victim. The broken nail was found at a second crime scene, where the victim was most likely assaulted. Finding and matching this missing nail implicated a suspect in this strangulation homicide. **(c)** The splinter hemorrhages in the middle and ring finger nail beds are signs of bacterial endocarditis and vegetations on the mitral or aortic heart valves. In this condition, small bacteria-laden emboli are disseminated throughout the arterial system into the nail beds, kidneys, and brain. **(d)** The brain shows hemorrhage from septic infarct, abscess, and stroke.

Figure 5.16 (a and b) Stab wounds found upon examination of the back. Bodies are difficult to turn over, so there is a natural tendency to forget to look at the back. Autopsy protocols are designed so that the back examination is not overlooked; in the case depicted, one would miss at least two stab wounds.

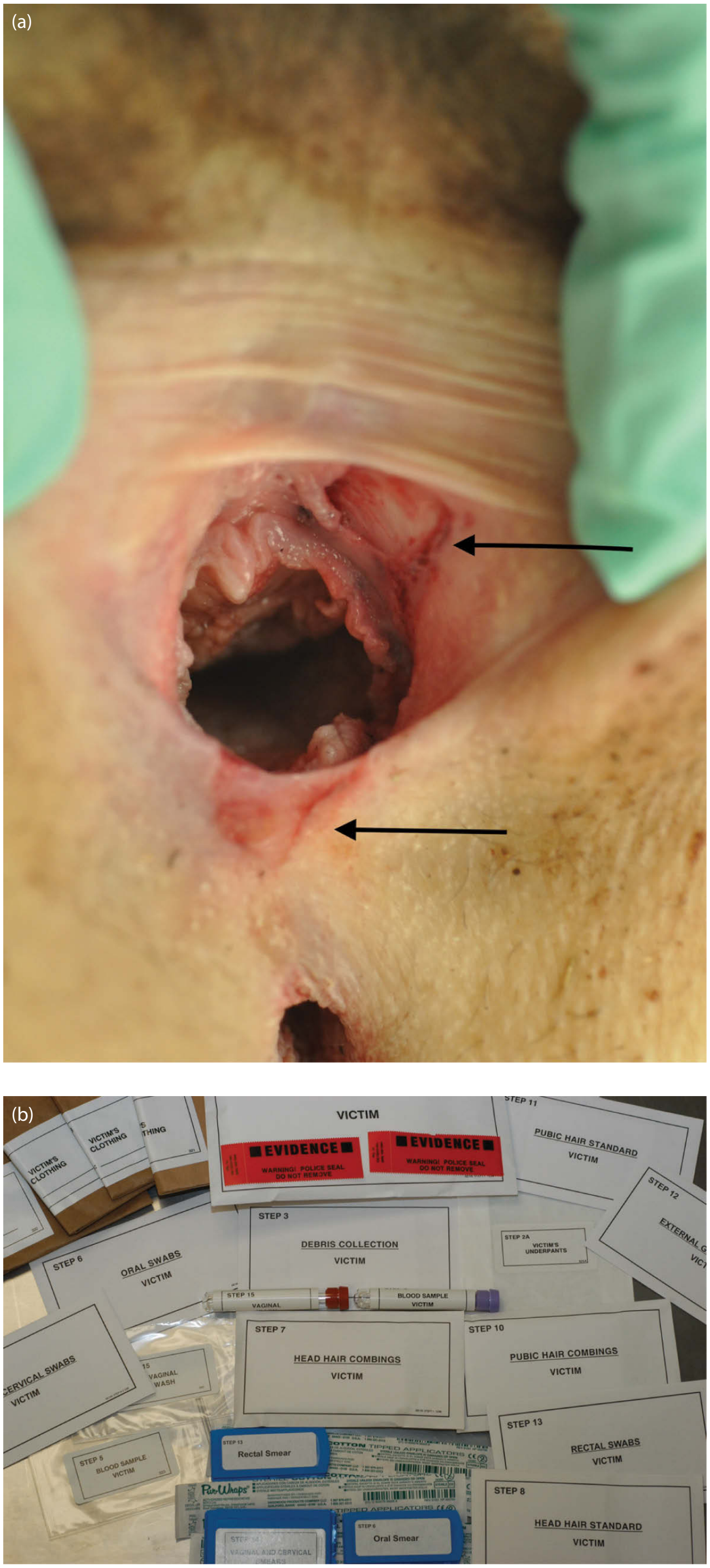


Figure 5.17 (a) Lacerations discovered on vaginal examination from sexual assault. Examination for sexual assault is essential in suspicious deaths. Excessive abrasion, laceration, or contusion of the genitalia usually indicates assault. The arrows point to two lacerations inside and outside of the vagina. **(b) Sexual assault kit.** A full sexual assault kit was obtained during this case, further confirming the assault. The victim was strangled to death during the assault.

Figure 5.18 Inflammatory bowel disease found upon anal examination. The anus is examined for assault and for medical conditions. The injury depicted shows multiple ulcerations and fistulae (see arrows) caused by inflammatory bowel disease, most likely Crohn's disease. The discoloration of tissues is a result of the decedent being in the early stages of decomposition. Inflammatory bowel disease causes ulcerations in the bowel wall and mucosa. If untreated, this disease can cause peritonitis and death.

CHAPTER 6

INTERNAL EXAMINATION: OPENING OF BODY CAVITIES AND INITIAL ASSESSMENT

As has been shown in Chapter 5, the external examination provides clues about what the pathologist can expect to find inside the body. During the internal examination, these leads are investigated. As with any investigation, some findings are completely unexpected. This means that the pathologist must examine all tissues carefully and objectively. Going into an autopsy with preconceived notions about potential findings can cause the pathologist to overlook the unexpected. For this reason, each internal examination includes, at minimum, an examination of the following:

- Heart, including coronary arteries and heart valves
- Chest cavity and mediastinum
- Lungs, lung hilum, and diaphragms
- Liver and gallbladder
- Spleen
- Stomach and esophagus
- Small and large intestines
- Bowel mesentery
- Peritoneal cavity
- Body walls
- Aorta and its branches
- Kidneys and adrenal glands
- Bladder and ureters
- Prostate
- Uterus and ovaries
- Neck organs and strap muscles, including larynx and thyroid gland
- Vertebral column
- Skull
- Brain and its coverings

This is a general list. Special cases or circumstances might require a more focused study of a specific tissue or organ system.

During the internal examination, the pathologist looks continuously for injuries and diseases with every cut of the knife. All of the senses (except taste, of course) are used. Tumors are often hard and can be palpated with the fingers. Hemorrhage can be seen in tissues that have deep, traumatic contusions. A smell of bitter almonds might indicate cyanide poisoning. Delicate crackles heard in the chest and mediastinal tissues indicate air in the tissues, or pneumothorax. The dissection is a careful, stepwise examination of the tissues and organs, usually performed in the same way so that nothing is forgotten. Most pathologists use their own routine protocols for dissection for this reason.

The reader should follow the figures page by page to experience the actual steps that are taken during the autopsy dissection (see Figures 6.1 through 6.40). (See Video 6.1.)

Figure 6.1 Placing the body on blocks. The shoulder region of the body is placed on rubber blocks. This freely exposes the neck. In addition, the shoulders naturally spread apart in this position.

Figure 6.2 (a–c) Initial incision. The body is opened with a Y-shaped incision extending from one shoulder to the other. The yellow subcutaneous fat is exposed. (*Continued*)

Figure 6.2 (*Continued*) (a–c) Initial incision. The body is opened with a Y-shaped incision extending from one shoulder to the other. The yellow subcutaneous fat is exposed.

Figure 6.3 Midline incision. The incision is extended to the midline abdomen, down to the midline of the pubic bone (pubic symphysis).

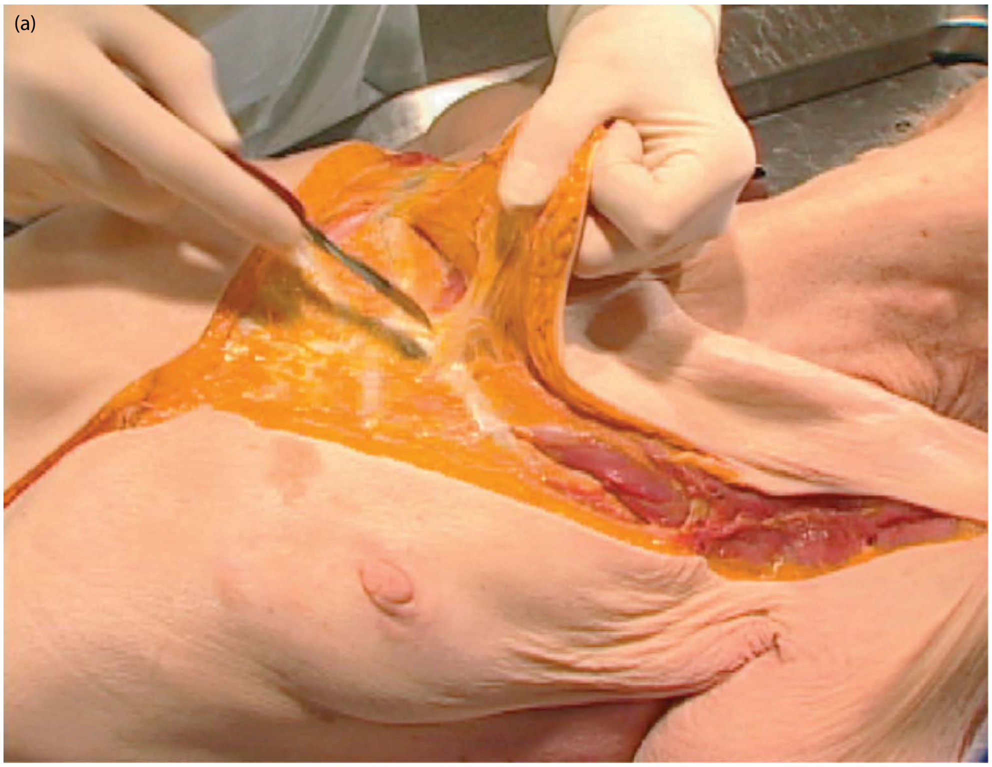


Figure 6.4 (a–c) Dissection of chest skin and soft tissue. The skin and subcutaneous tissue are dissected back to expose the underlying muscle and bone. The natural yellow color of the subcutaneous fat can be seen here. The soft tissue at the base of the neck can be seen in **(c)**. (*Continued*)

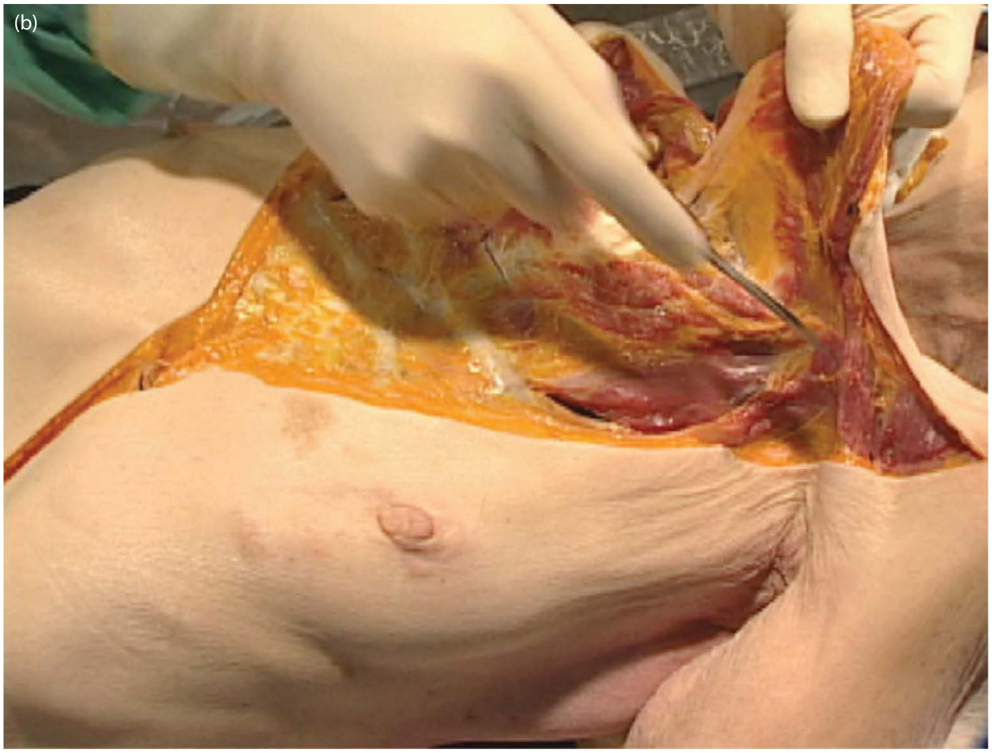


Figure 6.4 (*Continued*) (a–c) Dissection of chest skin and soft tissue. The skin and subcutaneous tissue are dissected back to expose the underlying muscle and bone. The natural yellow color of the subcutaneous fat can be seen here. The soft tissue at the base of the neck can be seen in **(c)**.

Figure 6.5 Cardiopulmonary resuscitation fracture of the ribs. The pathologist is constantly looking for injuries. This minimal focal hemorrhage is a result of rib fracture due to cardiopulmonary resuscitation. Fracture of these ribs during life would yield extensive, not focal, hemorrhage.

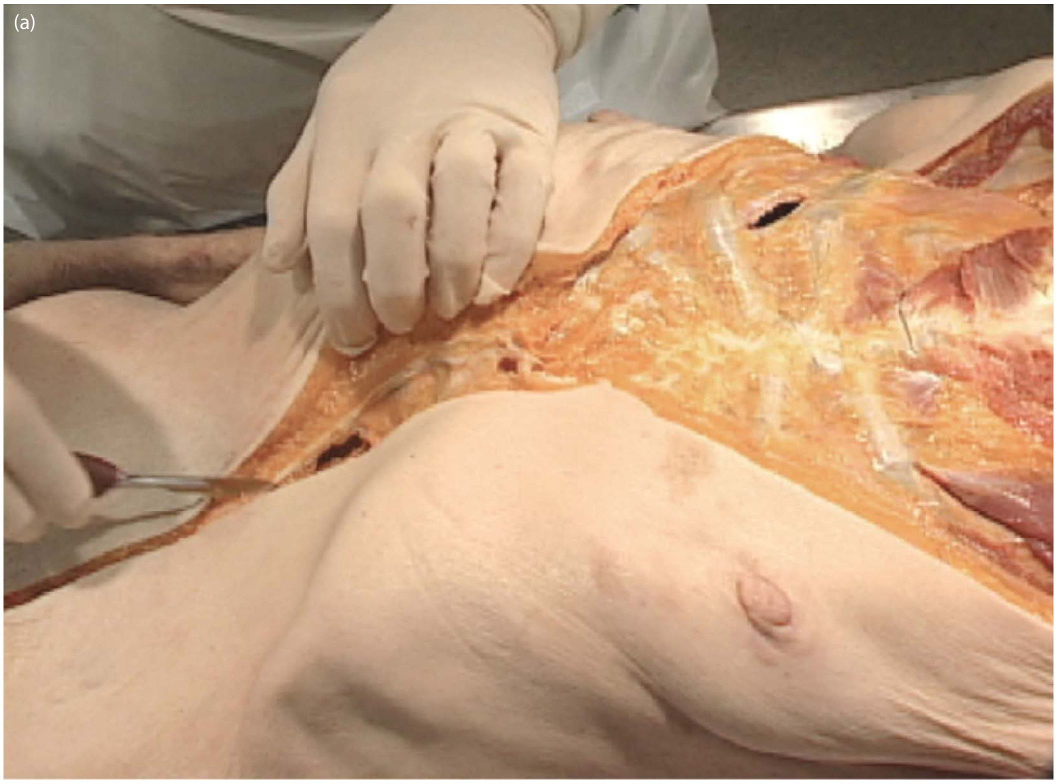


Figure 6.6 (a–c) Opening of the abdominal cavity. The abdomen is opened, exposing the underlying viscera. The pathologist is constantly looking for fluid, hemorrhage, or signs of inflammation in the abdominal cavity. (*Continued*)

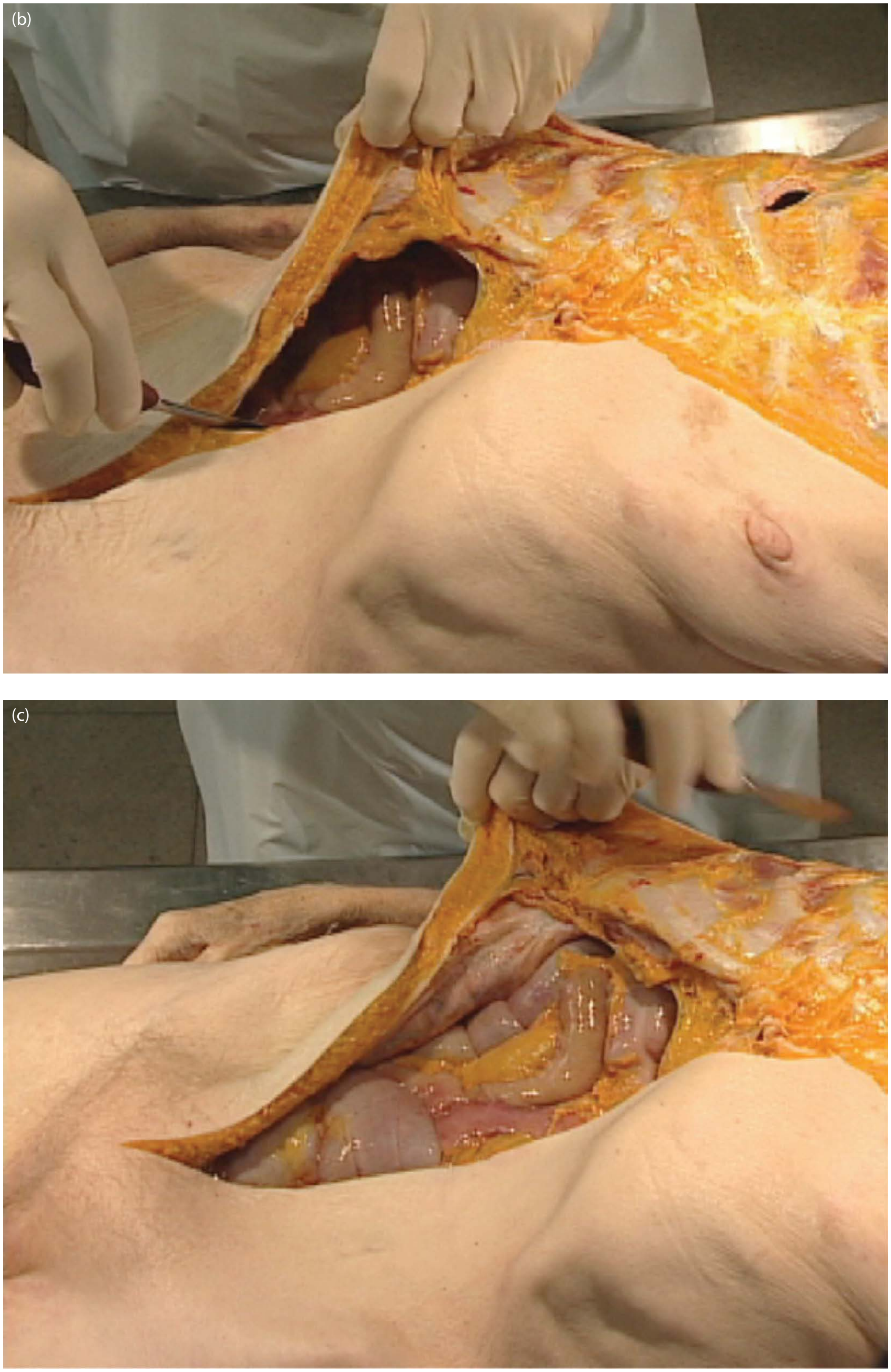


Figure 6.6 (*Continued*) (a–c) Opening of the abdominal cavity. The abdomen is opened, exposing the underlying viscera. The pathologist is constantly looking for fluid, hemorrhage, or signs of inflammation in the abdominal cavity.

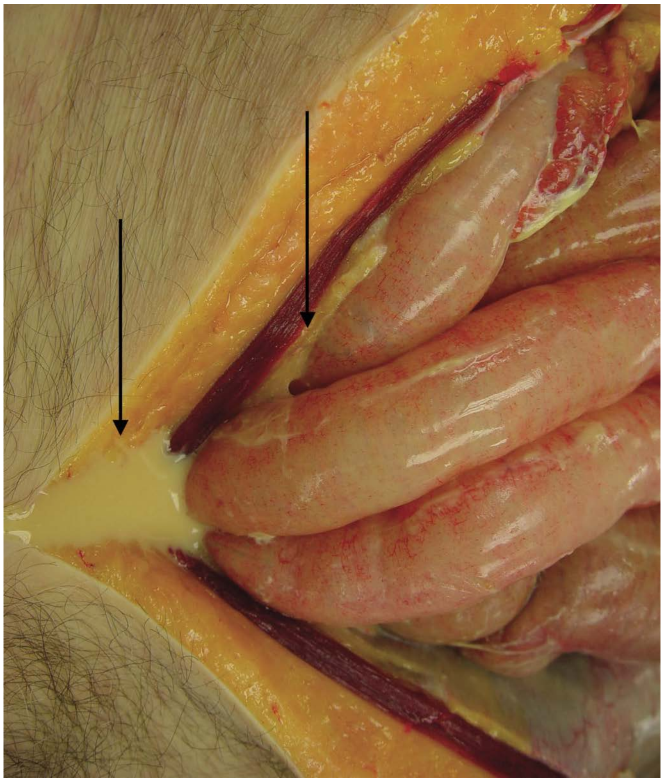


Figure 6.7 Pus in the abdomen. This figure shows yellowish pus, a sign of peritonitis. Microbiologic cultures can be taken to diagnose the source of infection. In addition, the abdomen will be searched for an anatomical source of this fluid, such as a perforated stomach ulcer.

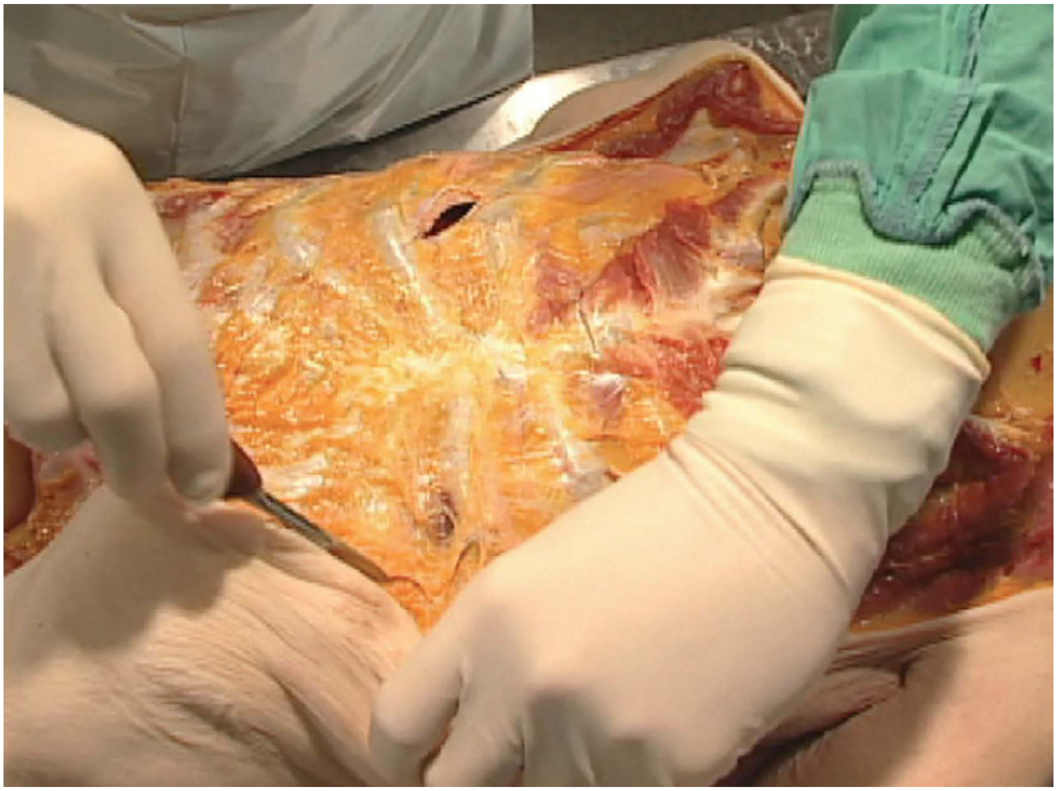


Figure 6.8 Marking the ribs. The ribs are marked for sawing.

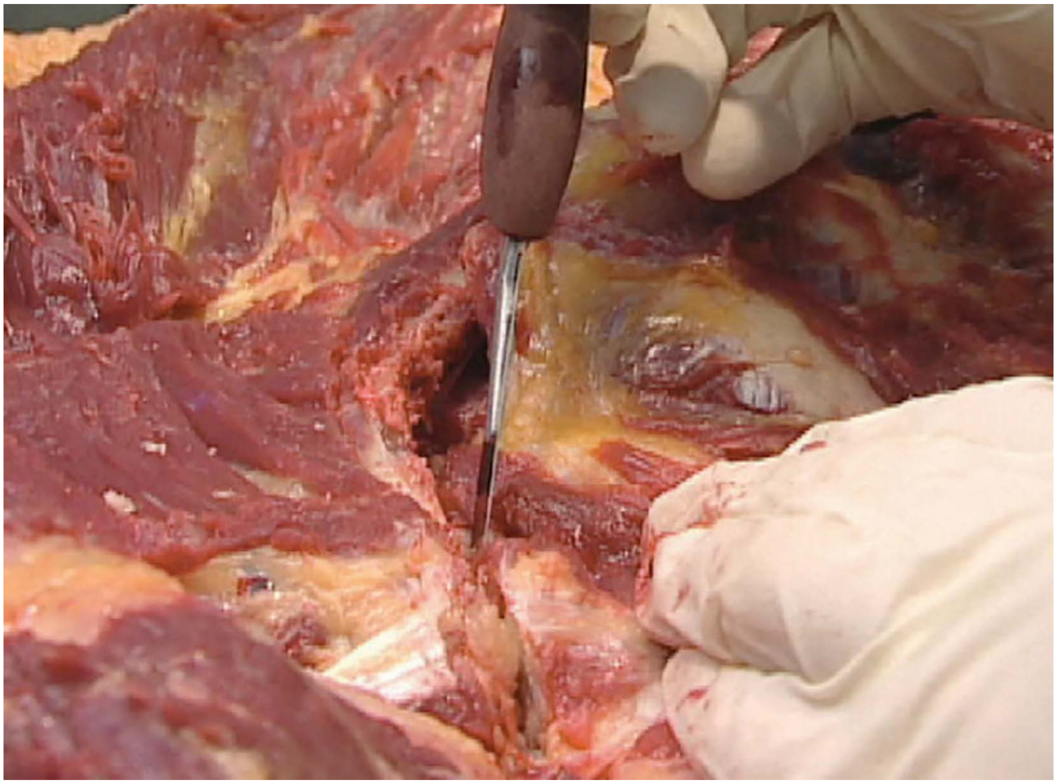


Figure 6.9 Sternoclavicular joint cut. The sternoclavicular joint is often cut because this thick joint can be difficult to saw.

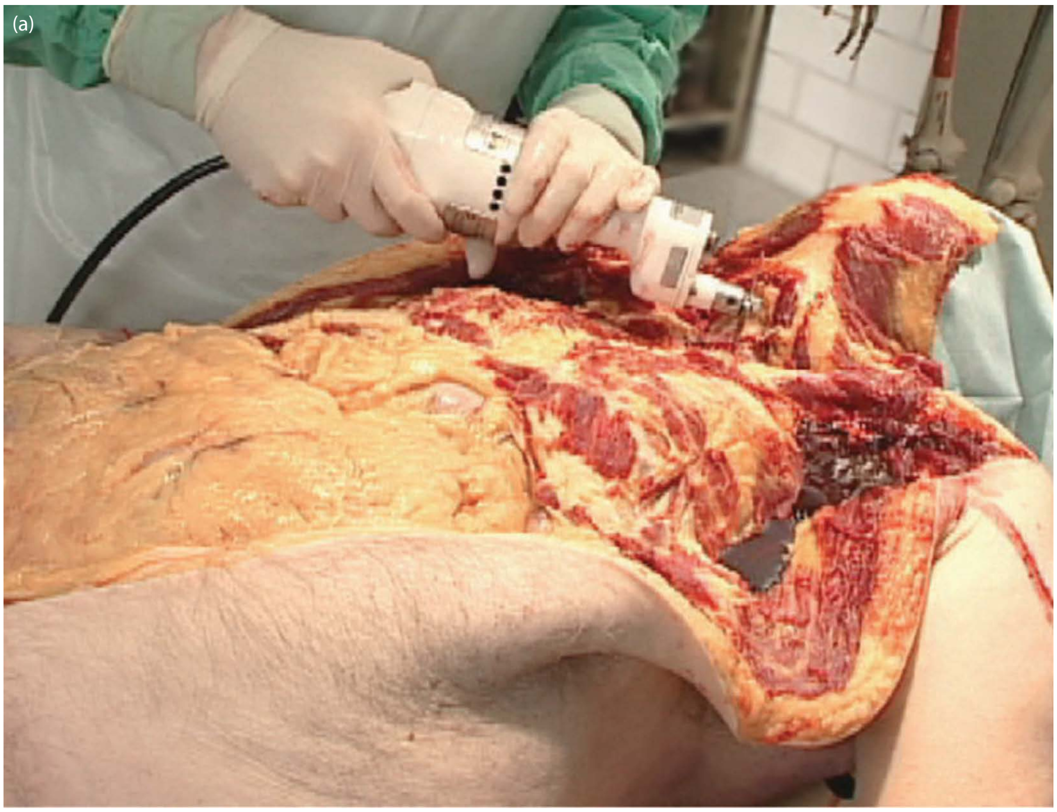


Figure 6.10 (a–c) Opening of the ribs with a bone saw. The ribs are sawed and opened with wide arcs to facilitate access to the chest organs and tissues. (*Continued*)

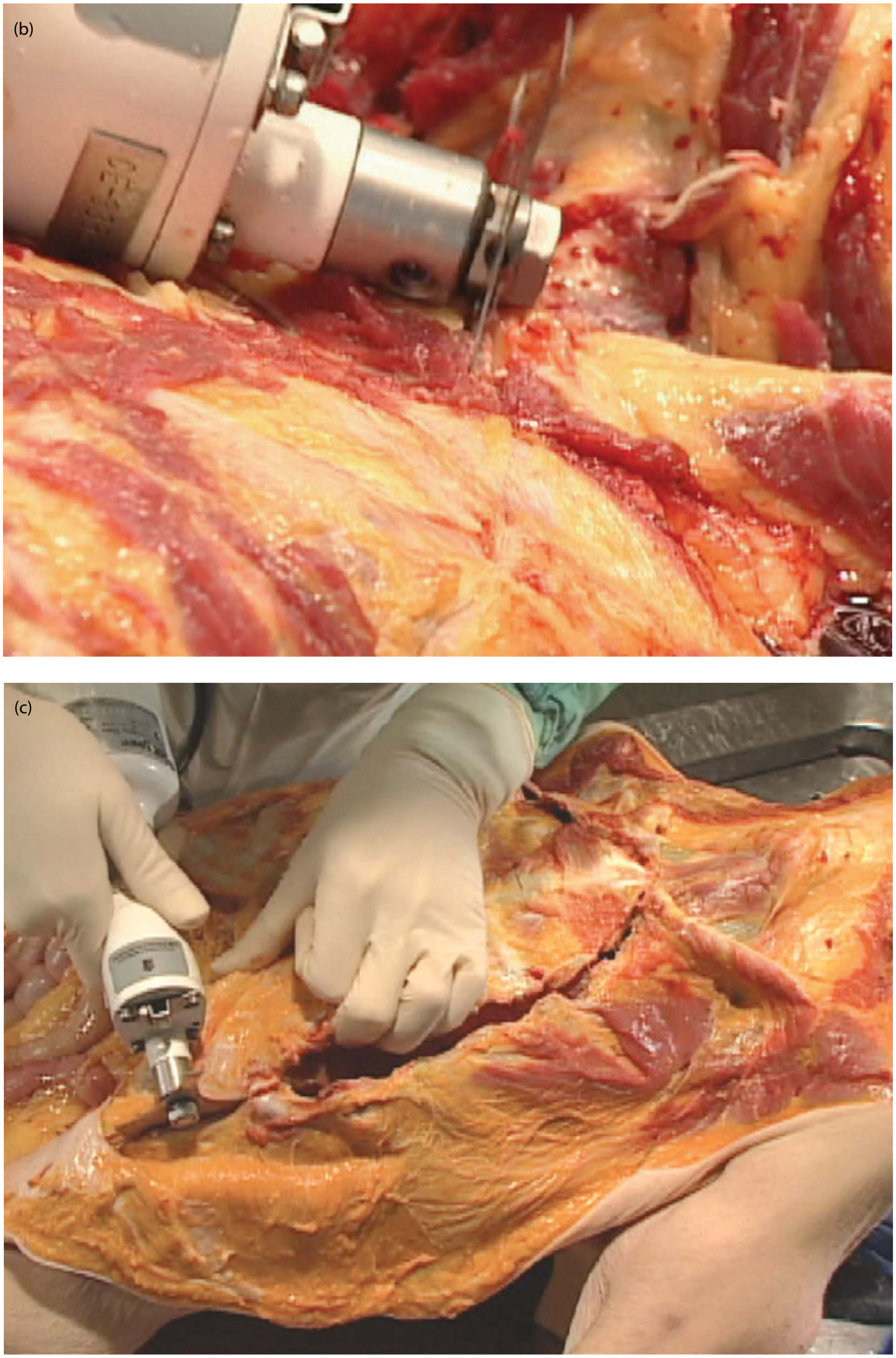


Figure 6.10 (*Continued*) (a–c) Opening of the ribs with a bone saw. The ribs are sawed and opened with wide arcs to facilitate access to the chest organs and tissues.

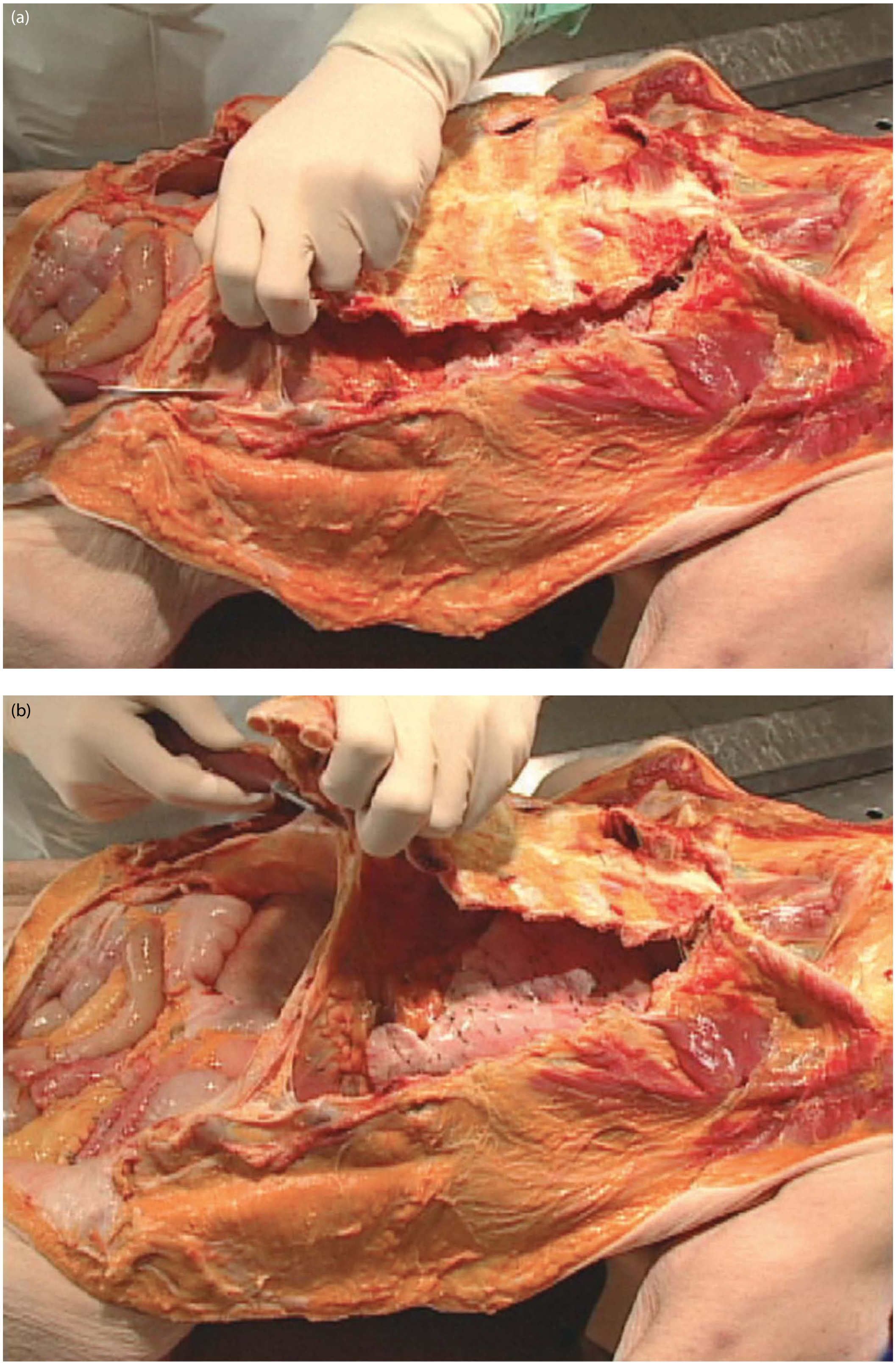


Figure 6.11 (a–d) Removing the "chest plate." The anterior diaphragm, uncut soft tissue, and soft tissue of the mediastinum are cut as the chest plate, or sternum, and ribs are lifted off. (*Continued*)

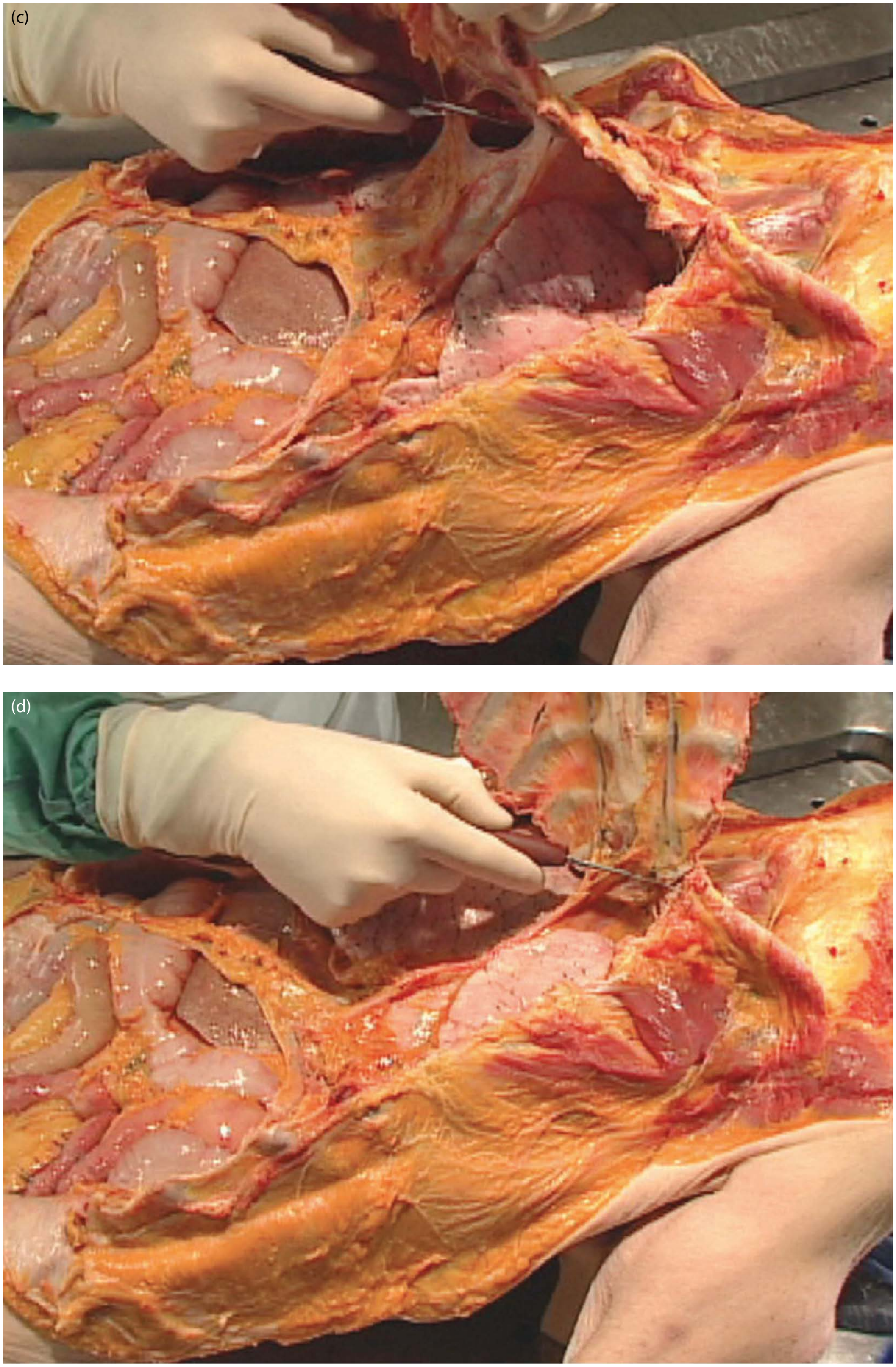


Figure 6.11 (*Continued*) (a–d) Removing the "chest plate." The anterior diaphragm, uncut soft tissue, and soft tissue of the mediastinum are cut as the chest plate, or sternum, and ribs are lifted off.

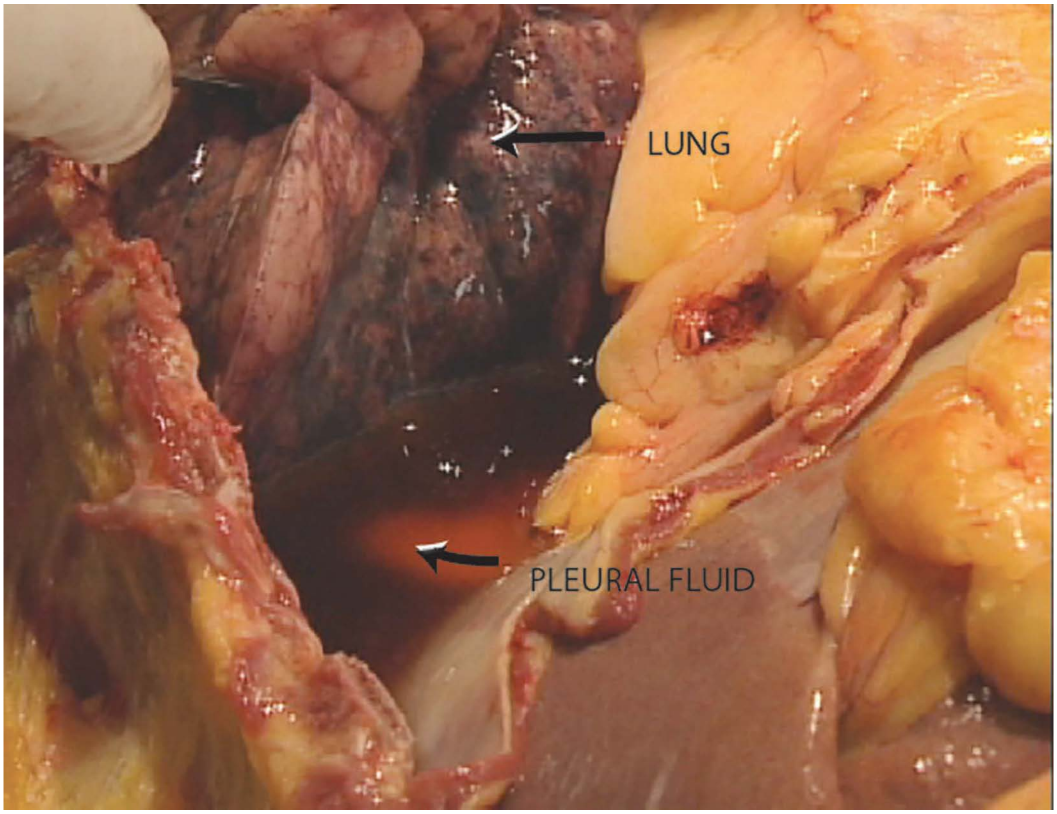


Figure 6.12 Fluid in the pleural cavity. Just as the sawed ribs are lifted up, inspection of this right chest cavity reveals serous fluid. The chest fluid here is the result of congestive heart failure. This failure of the heart as a pump results in fluid backing up in the lungs and chest. All fluids encountered are measured or closely estimated.

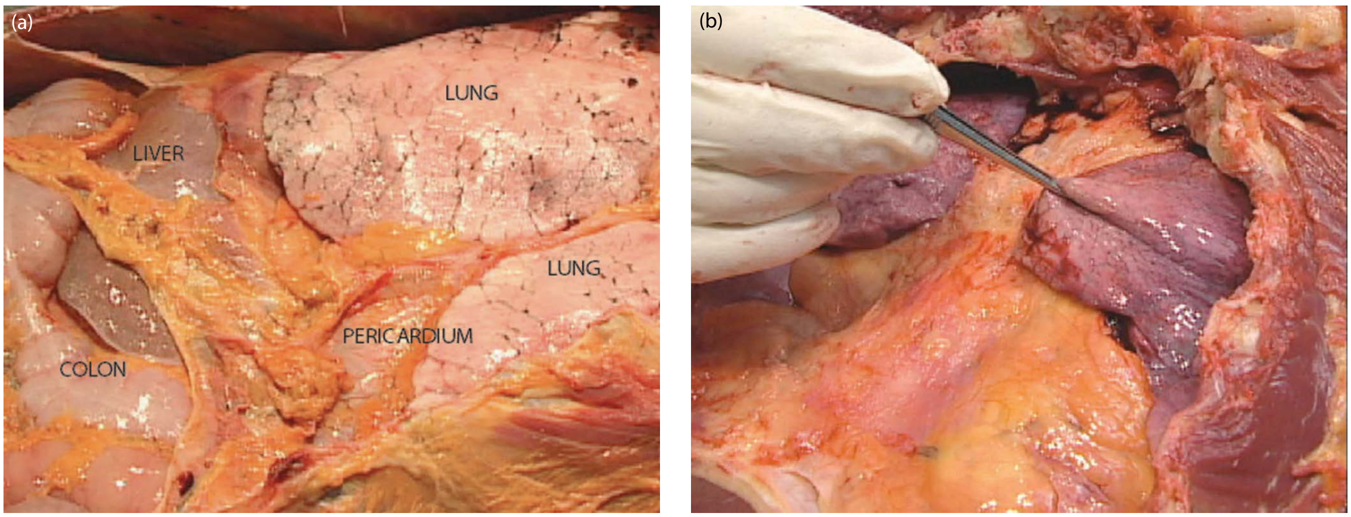


Figure 6.13 Survey of the lungs. (a) After the chest plate is removed, the lungs are examined in situ. The lungs here are situated normally in the chest. **(b)** The lung is held by the forceps.

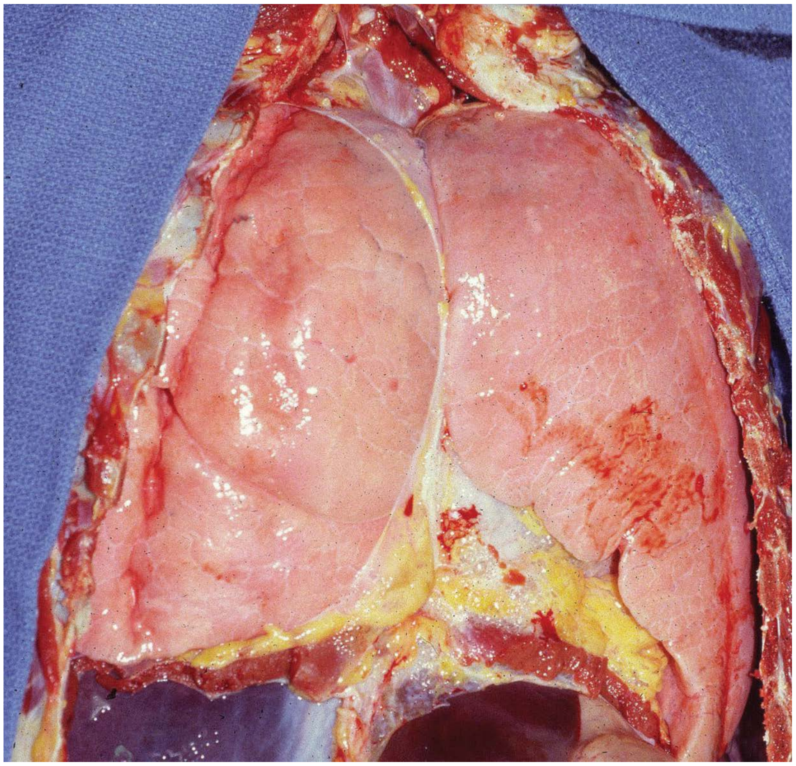


Figure 6.14 Hyperinflated asthmatic lungs. The lungs here show hyperinflation due to trapping of air. This patient died of a sudden asthma attack (status asthmaticus), during which bronchial spasm and mucous plugging hamper breathing, causing air to be trapped.

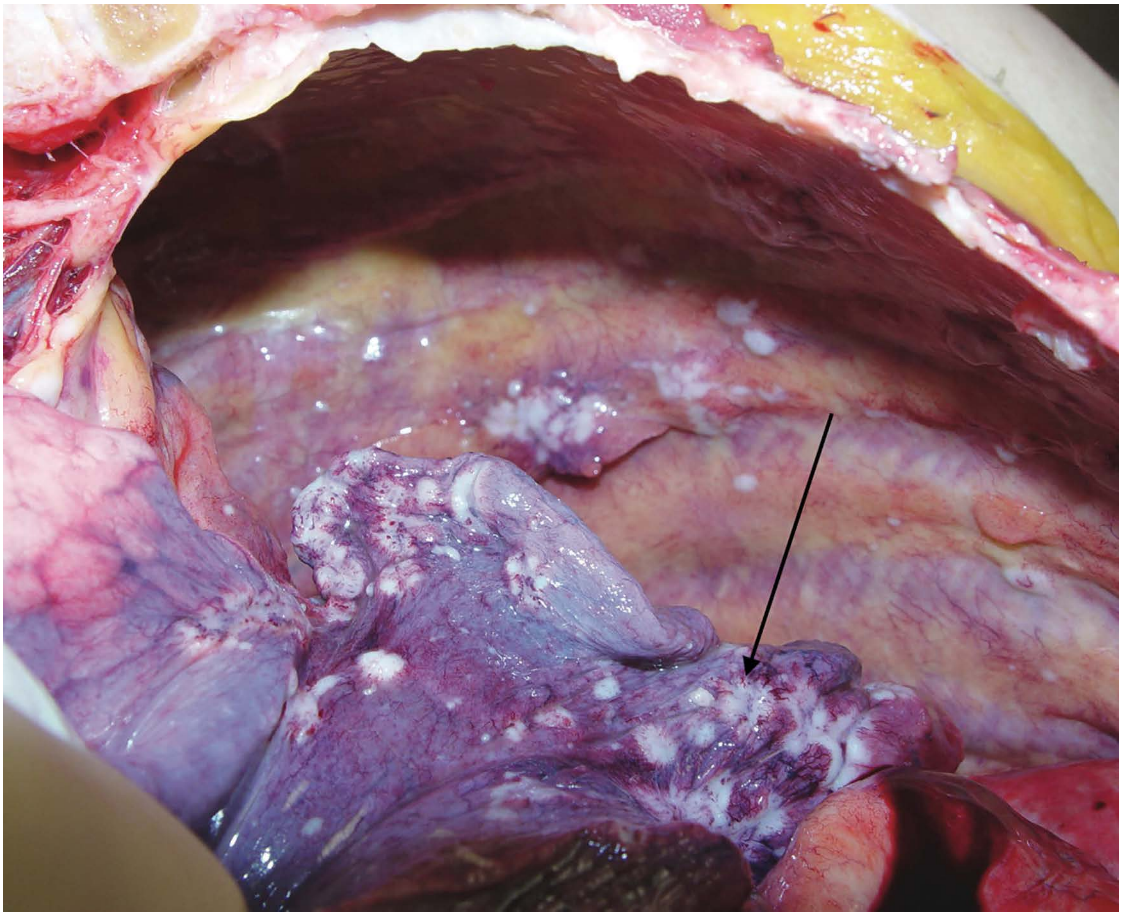


Figure 6.15 Metastatic carcinoma of the lung. Multiple white nodules on the lung pleura (covering) are from a carcinoma of the lung that has spread from the primary site (metastasized).

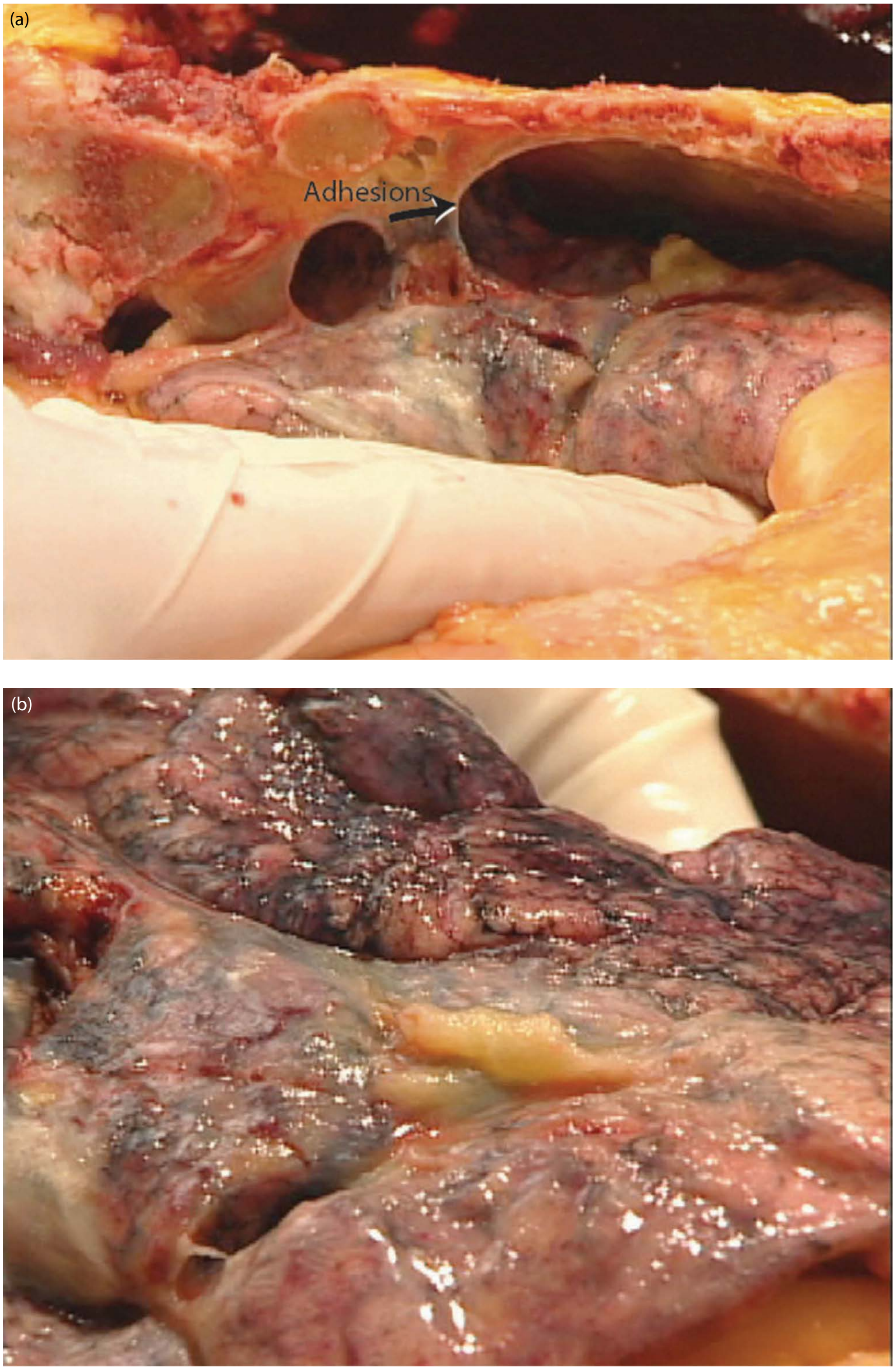


Figure 6.16 Lung and pleural adhesions. (a) Adhesions can be seen just below the cut ribs. **(b)** The covering of the lung, or pleura, shows a yellow exudate (center), also suggesting an inflammation of the lung and pleura, such as pneumonia.

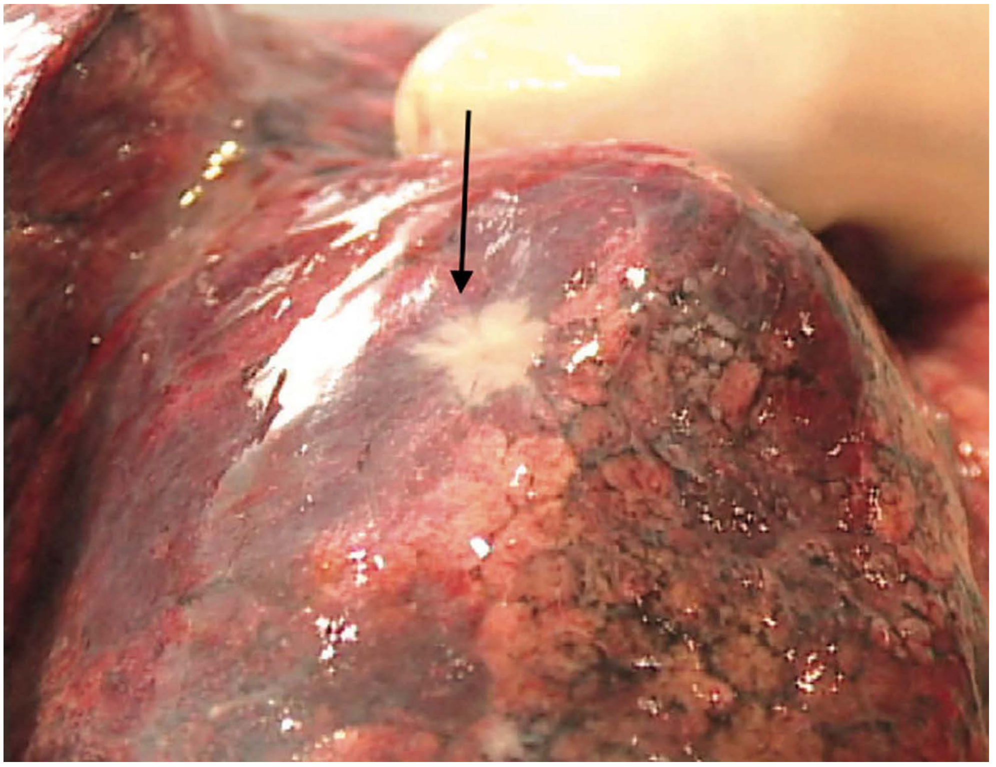


Figure 6.17 Pleural scar of the lung. Initial examination of this lung shows a whitish scar on the pleura. This is likely a healed focus of inflammation.

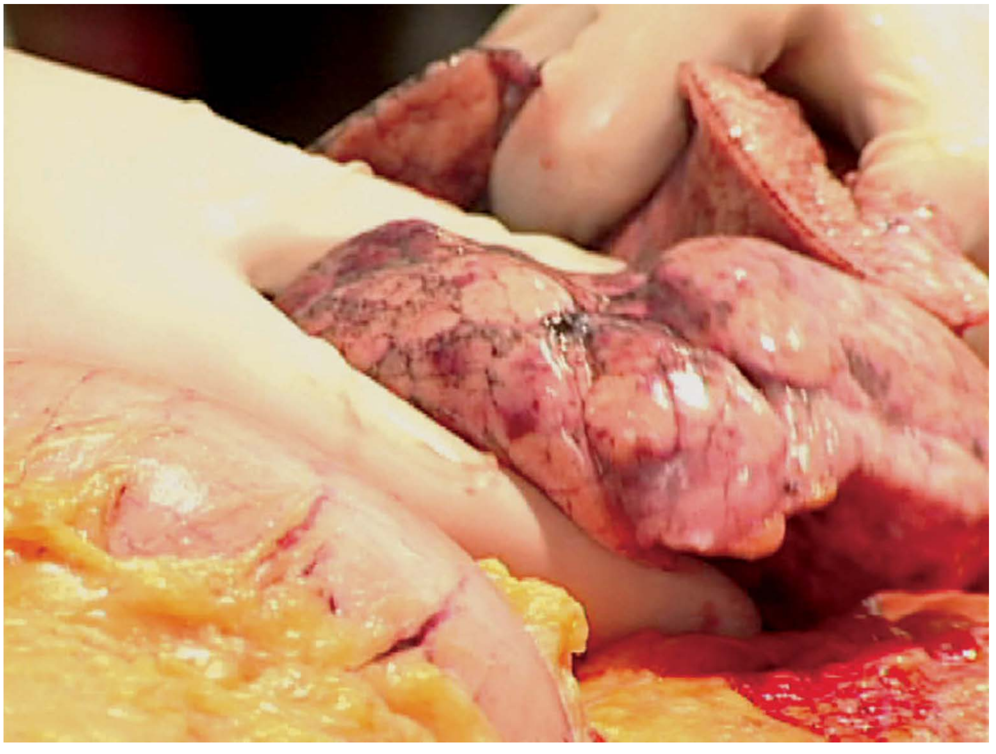


Figure 6.18 Palpation of mass in the left lung. The pathologist uses the sense of touch to feel for masses. Tumors are commonly firm to the touch. The pathologist is palpating a tumor between the thumb and forefinger. This tumor will be dissected later in the organ examination (see Figure 8.37).

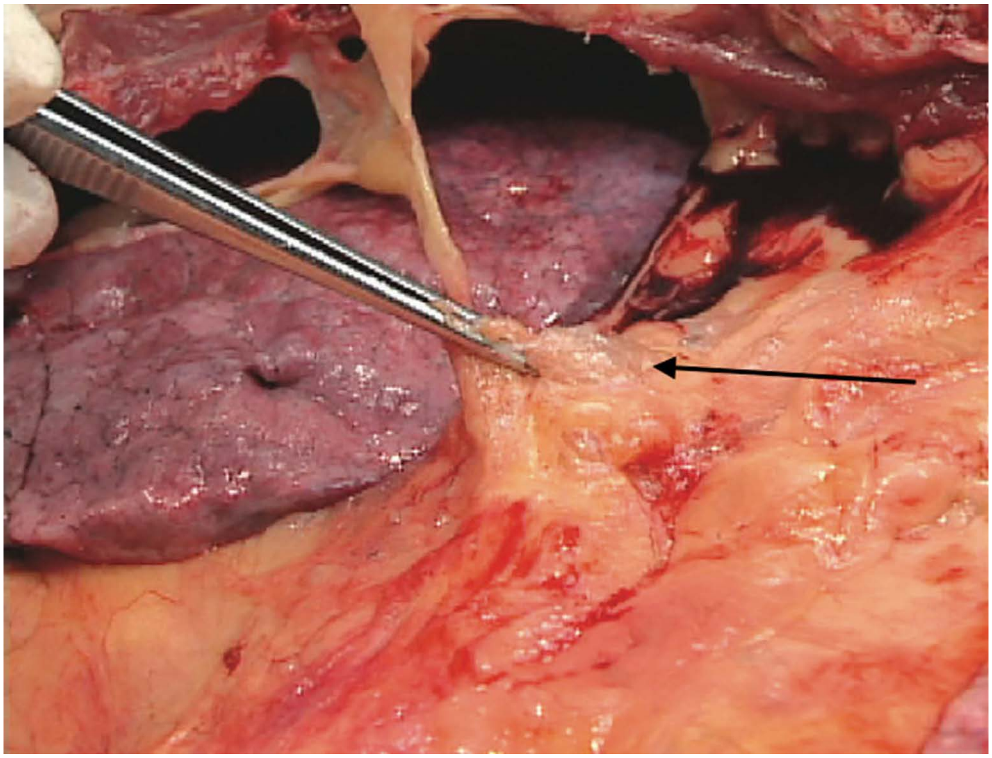


Figure 6.19 Pericardial air bubbles. Small "bubbles" in the tissue, as seen here between the forceps, indicate dissection of air from the lung into the chest cavity and surrounding soft tissue of the chest (pneumothorax). The cause of pneumothorax in this figure is a rib fracture from cardiopulmonary resuscitation.

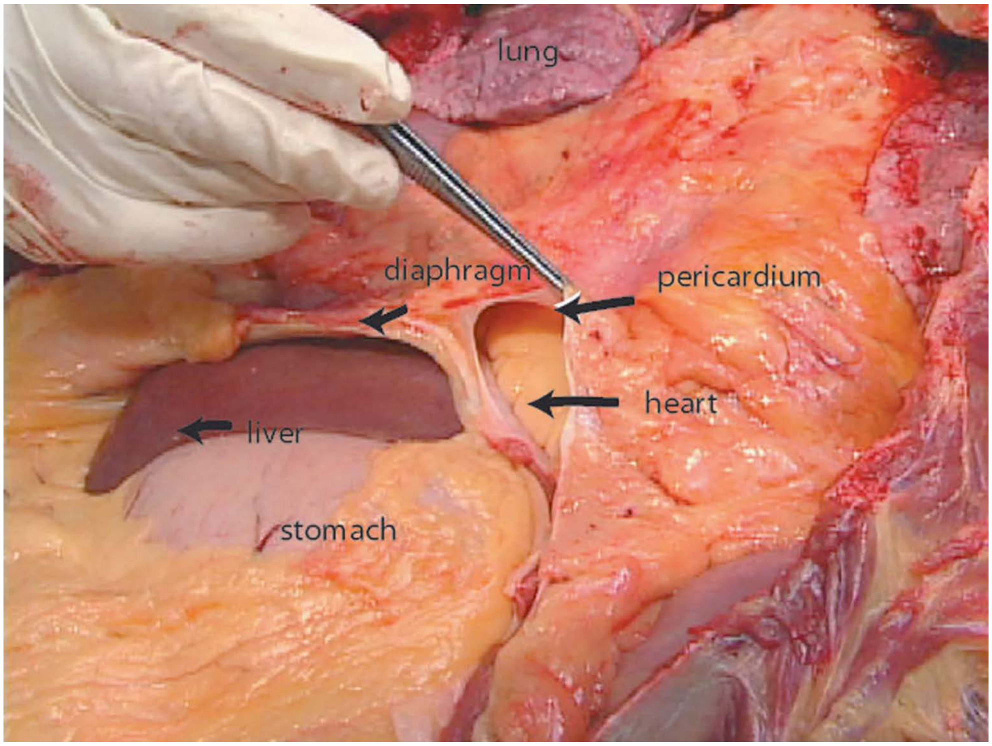


Figure 6.20 Pericardium displayed. The pericardium (heart lining) has been opened and is lifted up by the forceps. The heart is contained within. The fat-covered tip of the heart can be seen. The liver is dark brown just below, resting on the stomach.

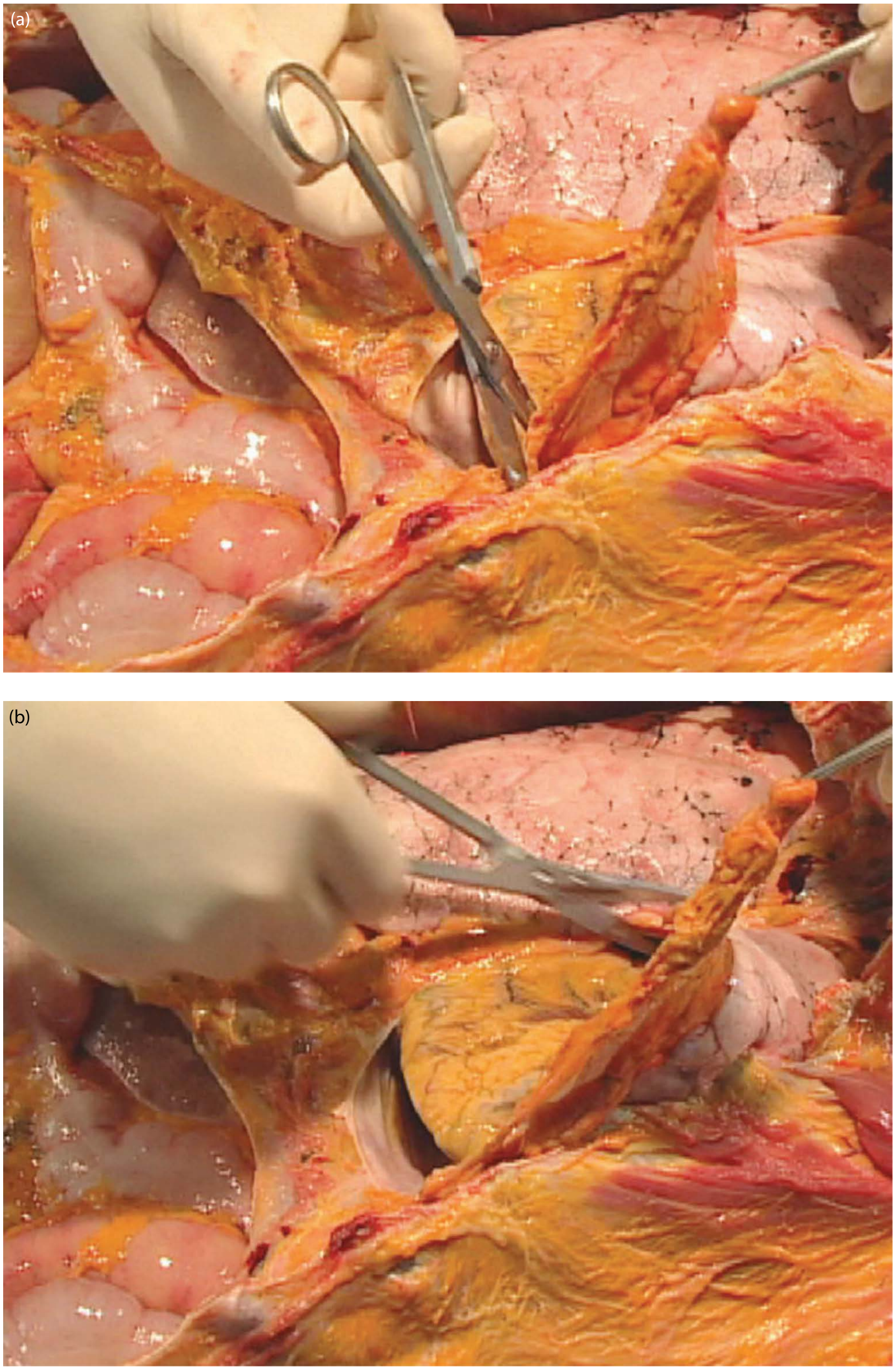


Figure 6.21 (a and b) Opening of the pericardium. The pericardium is opened to look for fluid and inflammation.

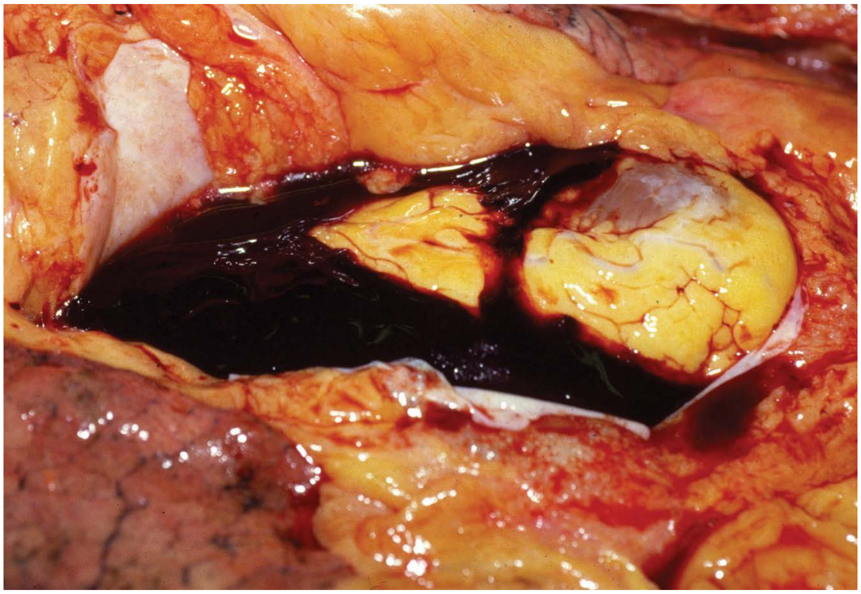


Figure 6.22 Hemopericardium. Blood can be seen filling the pericardium. This patient had suffered a myocardial infarction approximately 5 days previously. The infarcted (dead) heart tissue burst open, allowing for hemopericardium. The blood in the pericardium interferes with the contraction of the heart (cardiac tamponade) and can cause cardiac arrest.

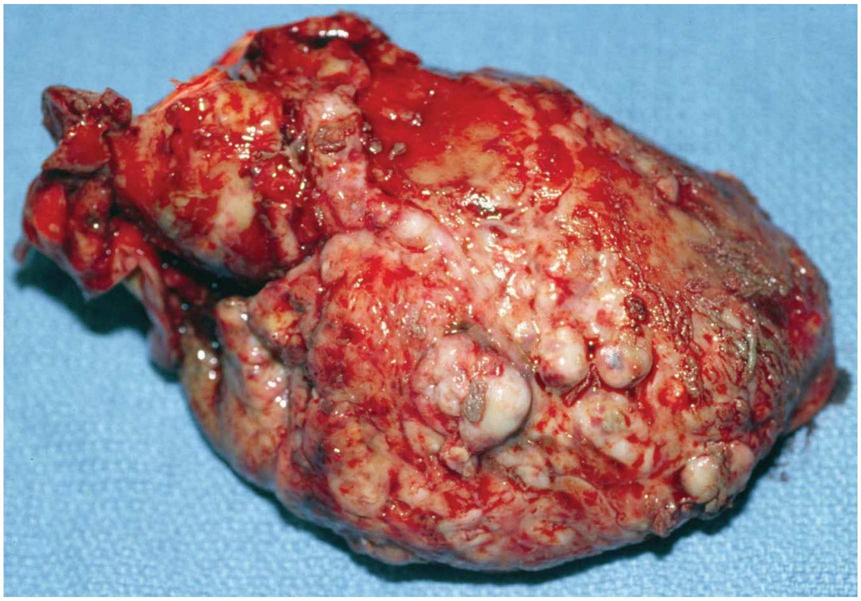


Figure 6.23 Metastatic carcinoma of the heart. The epicardium (outer surface of the heart) is covered with metastatic tumor nodules. The diagnosis of carcinoma will be confirmed by microscopic examination (see Figure 10.6).

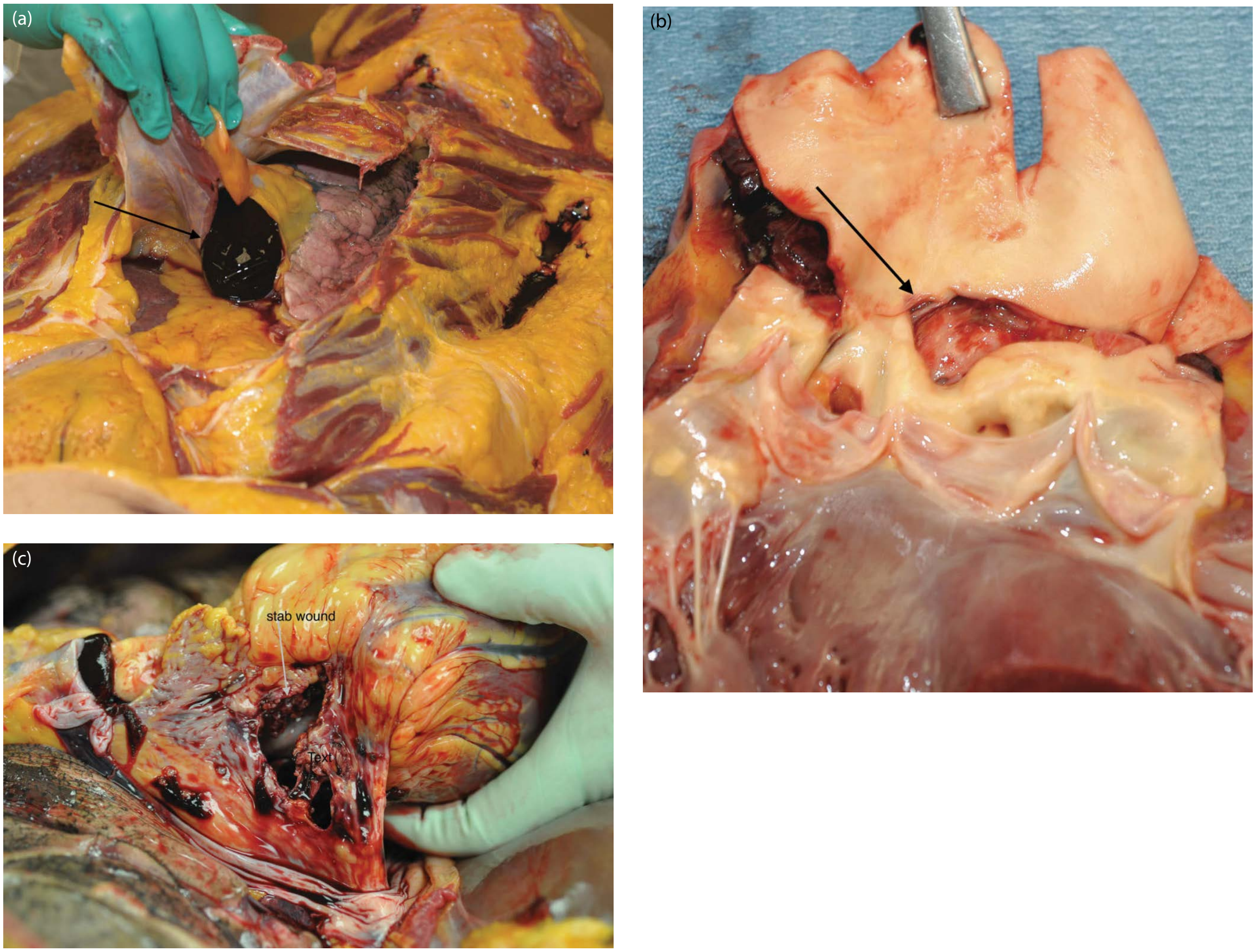


Figure 6.24 Hemopericardium. (a) A large, approximately 200-cc hemopericardium is seen. **(b) Aortic laceration.** Once the clot is evacuated and the heart removed, the source of the blood is found to be an aortic dissection near the aortic valve. Since this part of the aorta is within the pericardial sac, the blood is found here. **(c) Stab wound of heart.** A large cut is seen in the right atrium due to a stab wound with a knife.

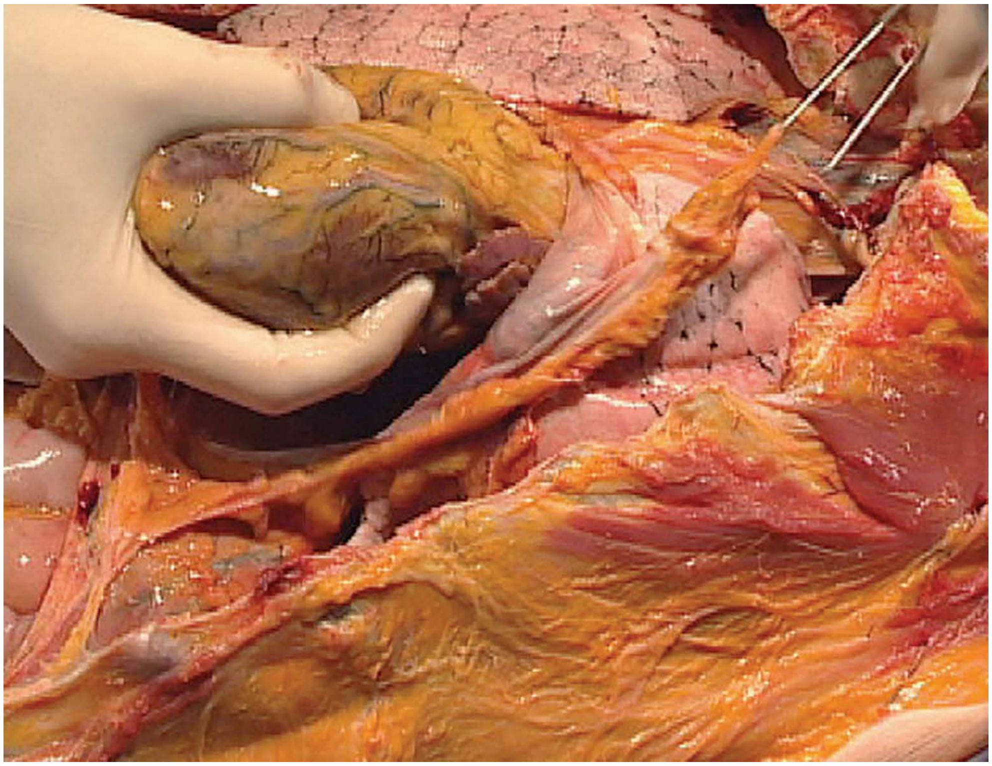


Figure 6.25 Palpation and examination of the heart in situ. The heart is palpated and visually examined in situ. Soft areas in the heart may indicate infarction. A diffusely soft heart might indicate myocarditis.

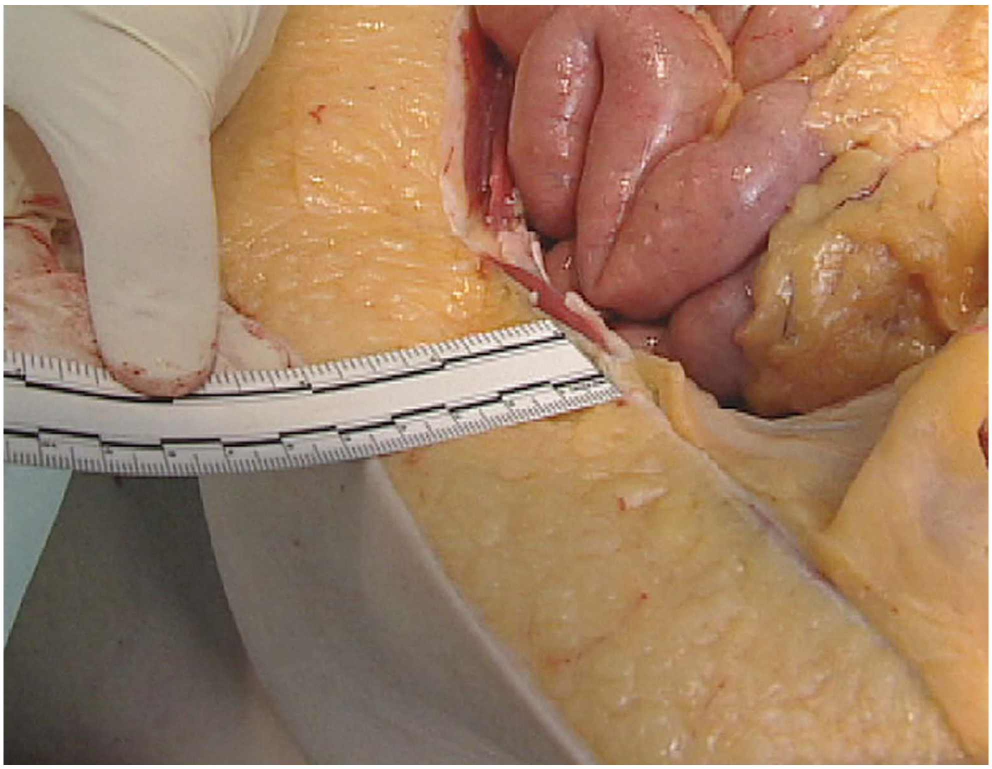


Figure 6.26 Abdominal panniculus. The abdominal panniculus (fat pad) is measured and recorded. The panniculus is greatly thickened in obesity and razor-thin in malnutrition.

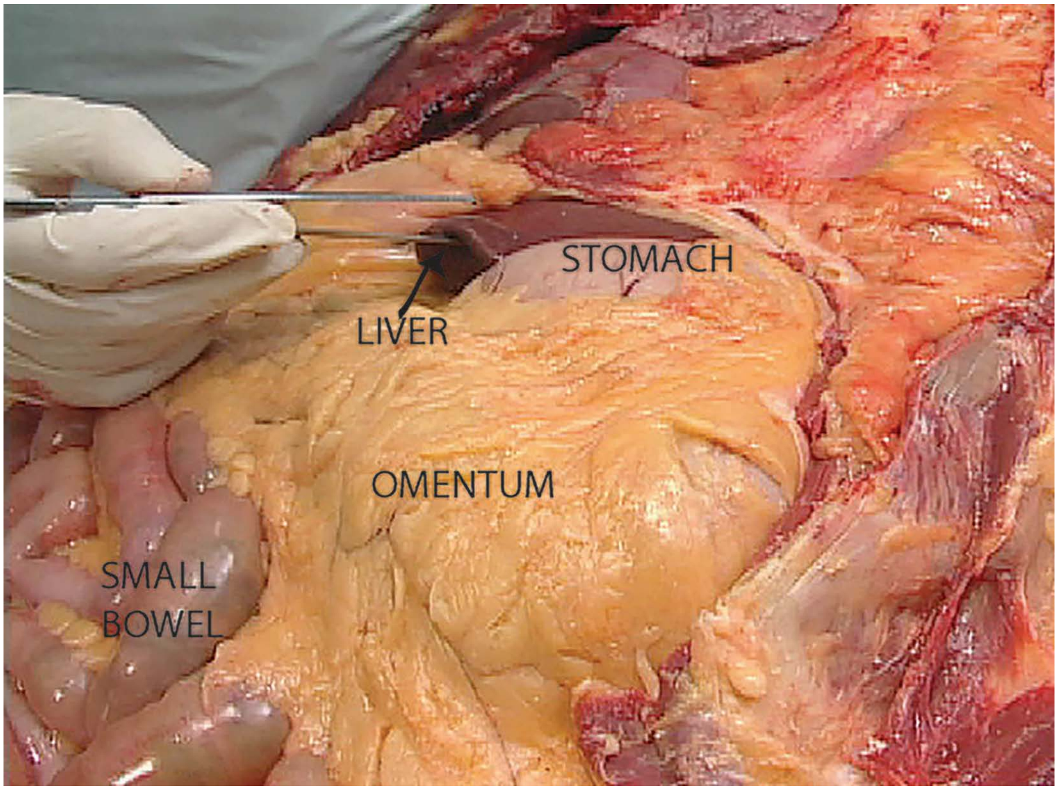


Figure 6.27 Upper abdominal organs. The liver is lifted up with the forceps as it rests on the stomach. The omentum (protective fat layer) is seen below the stomach, partially covering the bowel.

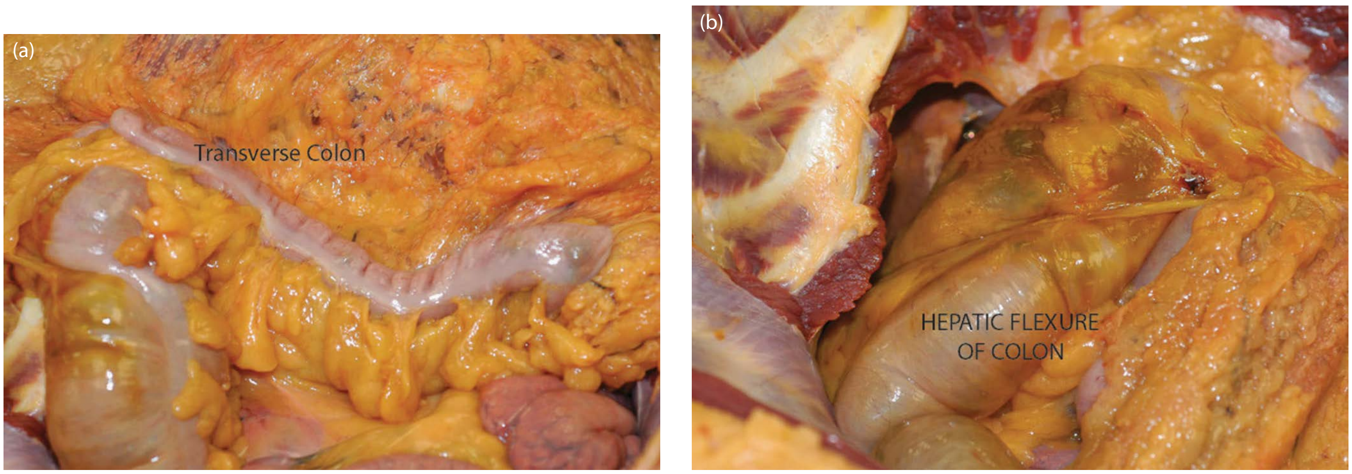


Figure 6.28 Omentum and colon. (a) If the omentum is reflected back, the transverse colon is exposed. **(b)** The hepatic flexure of the colon can be seen just below the ribcage. This is the point where the ascending colon turns into the transverse colon at the liver.

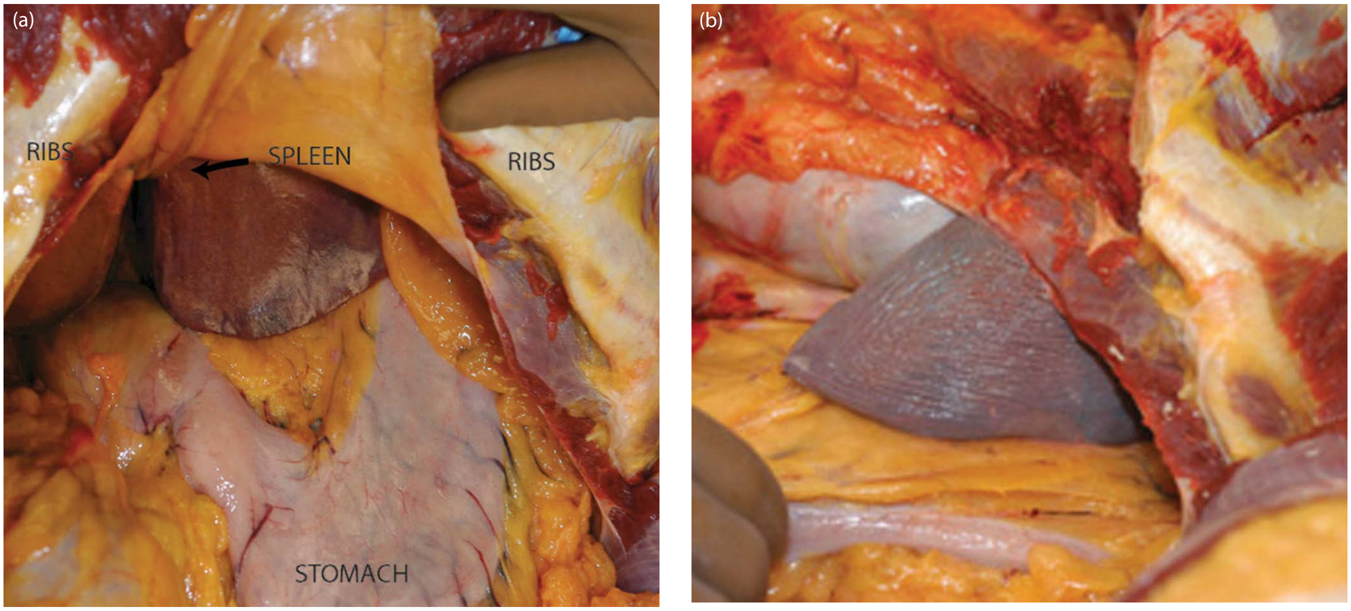


Figure 6.29 Spleen in situ. (a) The dark brown spleen can be seen in the upper part of the picture just above the stomach. This spleen is free of laceration. Laceration is common in severe blunt trauma to the abdomen. **(b)** The spleen is in the middle of the picture, and the whitish descending colon is at the bottom of the figure. Anatomically, the spleen is located in the left upper quadrant of the abdomen under the ribcage.

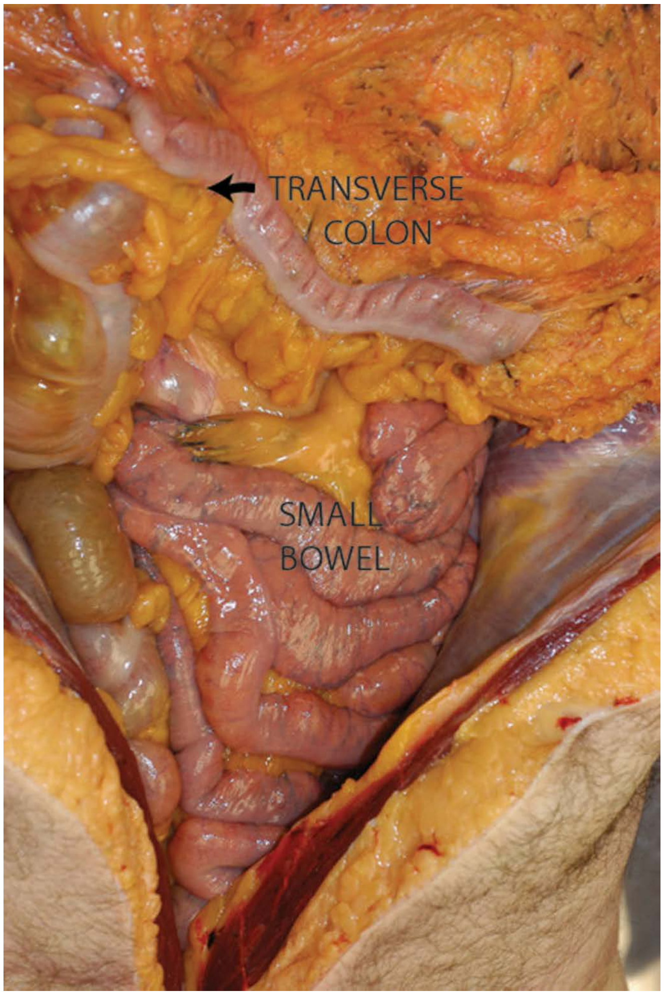


Figure 6.30 Transverse colon and small bowel in situ. The normal bowel is in the proper location, extending transversely across the abdomen. The transverse colon is surrounded by connective fat at the top of the figure, and the small bowel is bunched together in a zigzag fashion on the bottom.

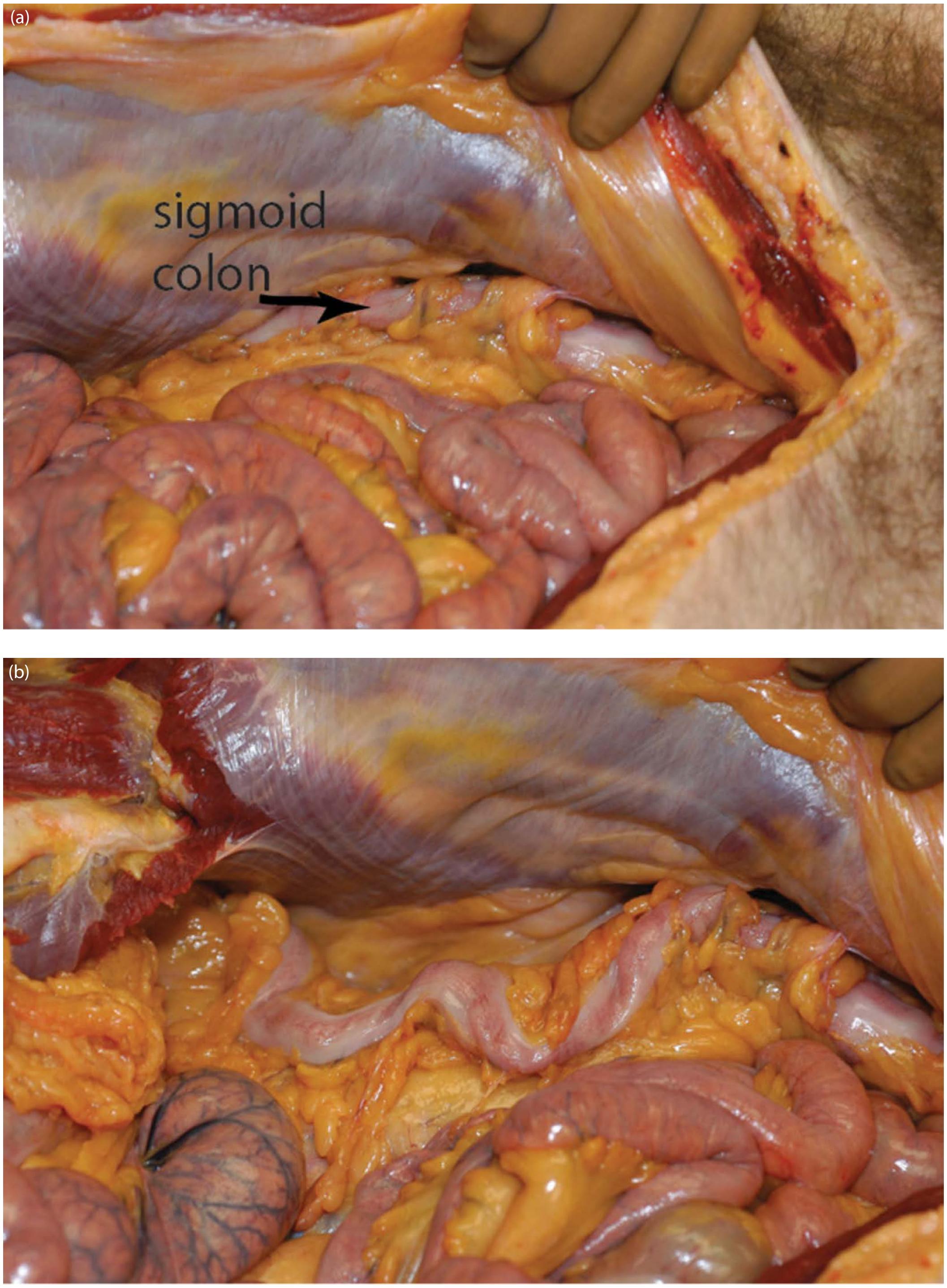


Figure 6.31 Sigmoid colon. (a) The whitish sigmoid colon is behind the reflected abdominal wall, amid the small bowel in the foreground. **(b)** The bowel is pulled out slightly, exposing its course.

Figure 6.32 Inflammation of the abdomen and bowel. Survey of the bowel in this case reveals a whitish–yellow (fibrinopurulent) exudate, indicating an ongoing (subacute) infection of the abdominal cavity. Notice how reddened (erythematous) the bowel appears. This erythema indicates inflammation.

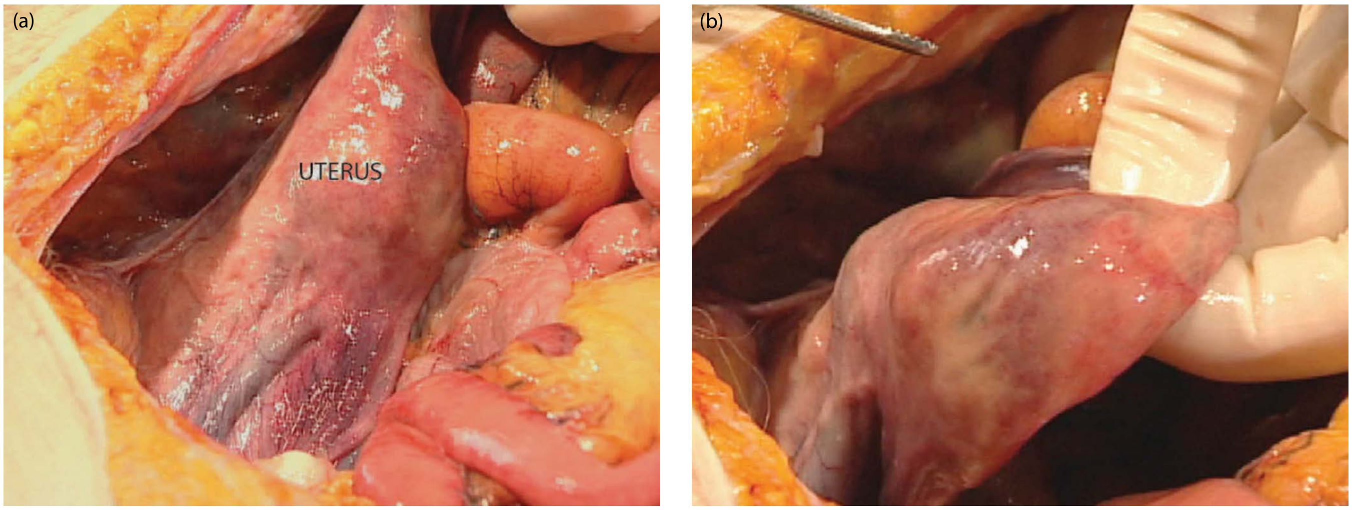


Figure 6.33 Uterus in situ. (a) The uterus is in the midline of the pelvis. **(b)** No lesions are seen as it is examined in situ.

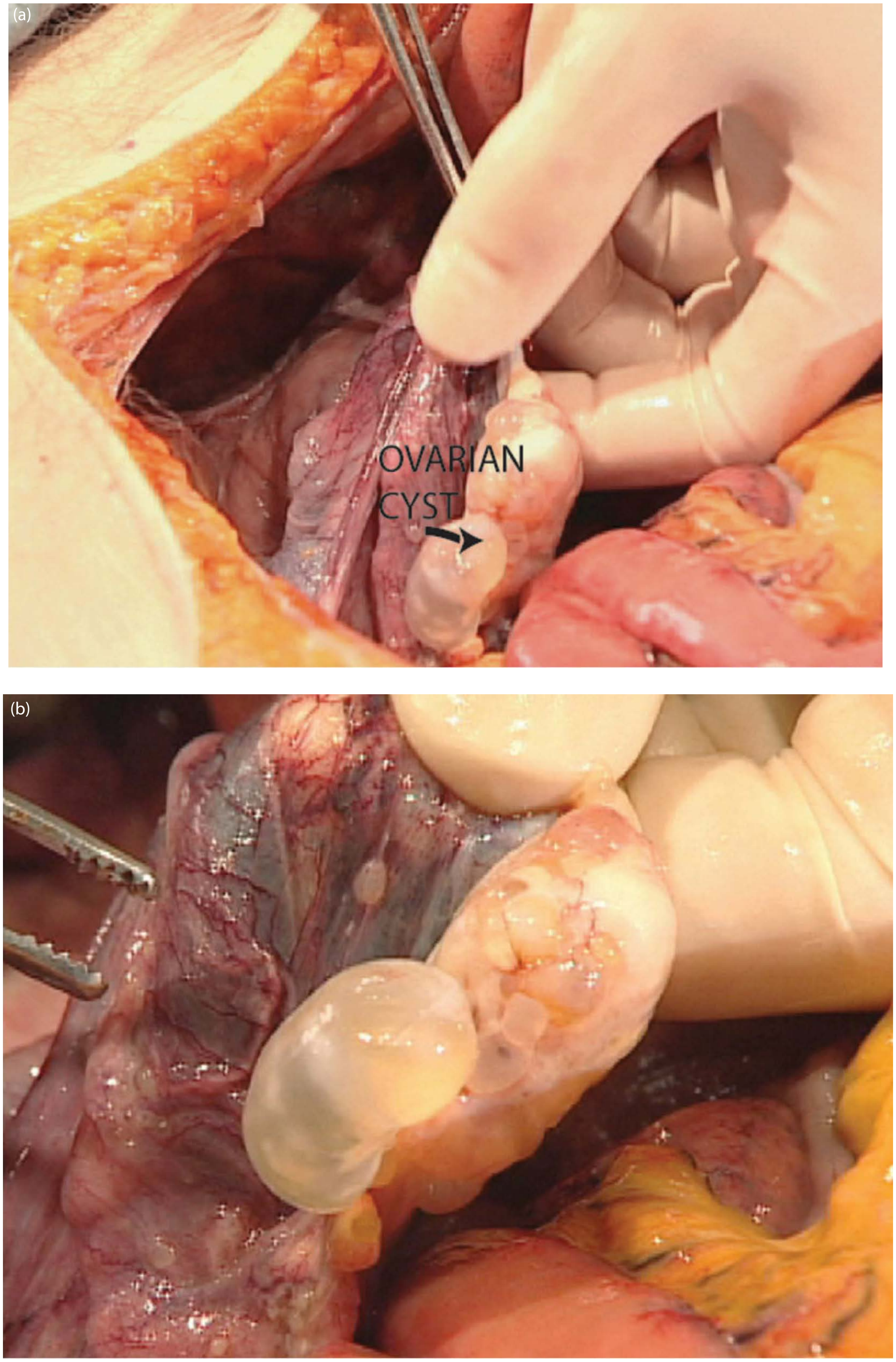


Figure 6.34 Small ovarian cyst. (a) A small ovarian cyst can be seen on this left ovary. **(b)** It is better seen when pulled out.

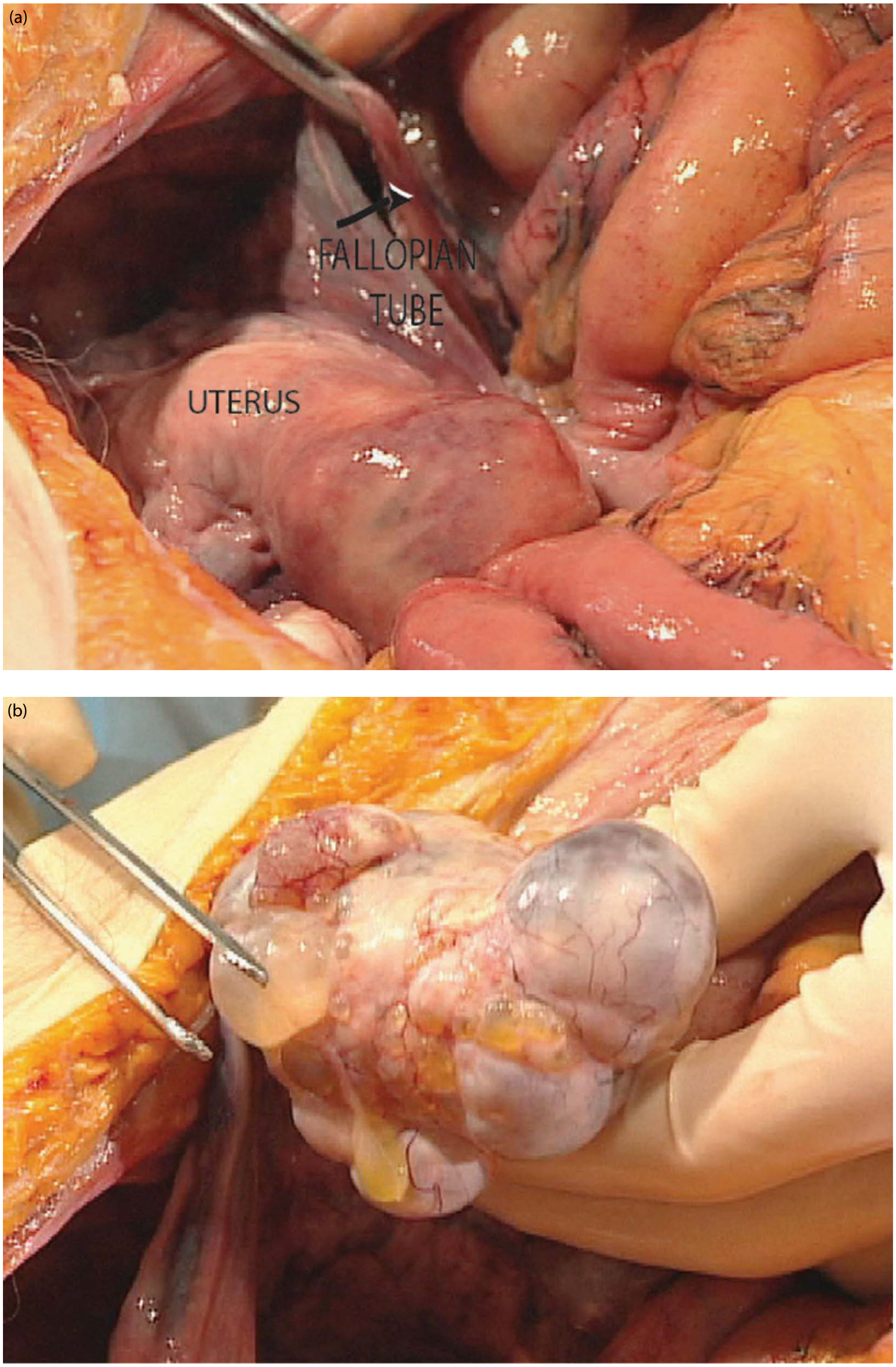


Figure 6.35 (a and b) Large ovarian cyst. Pulling on the left fallopian tube reveals a much larger cyst of the right ovary.

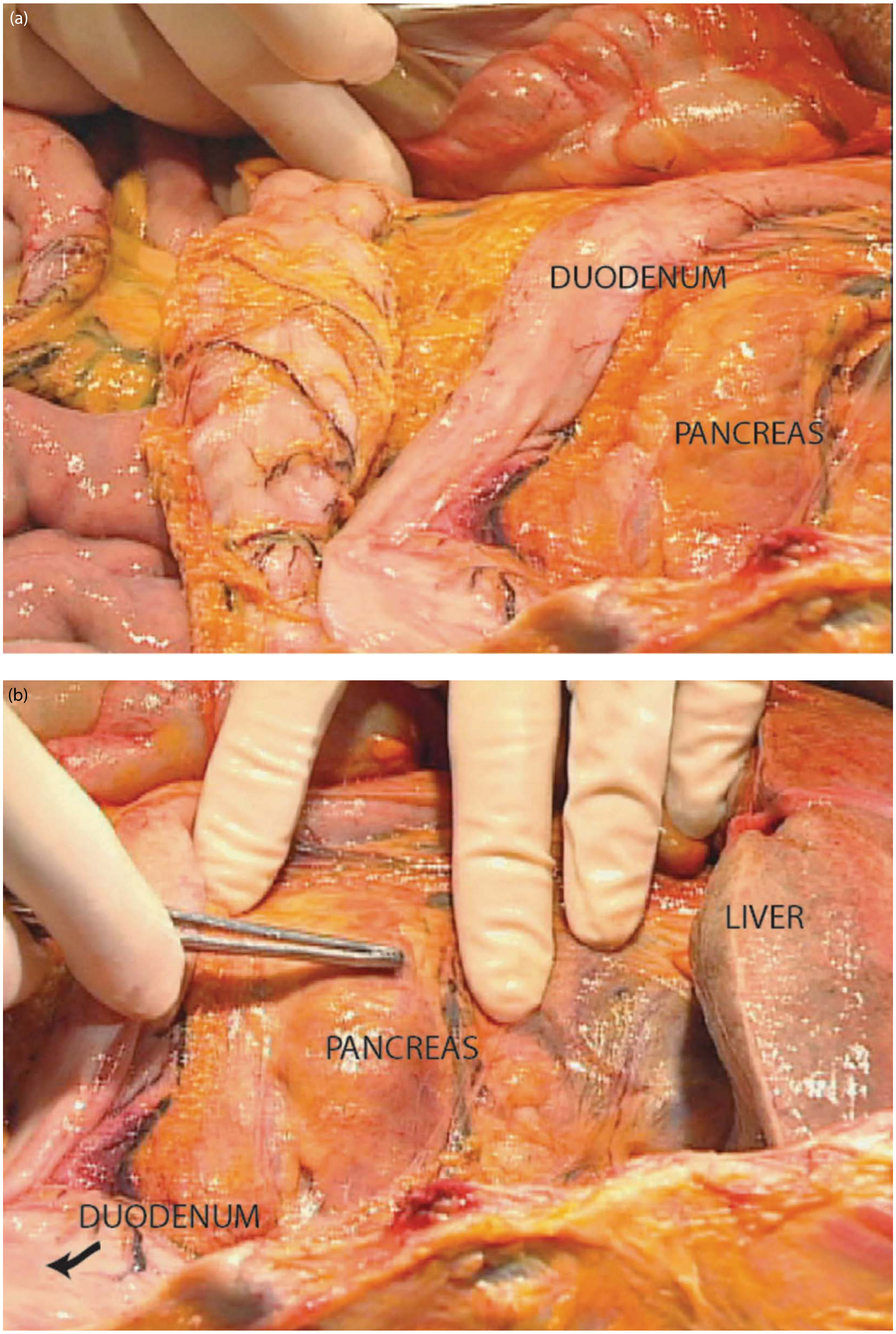


Figure 6.36 Pancreas and duodenum. (a) The duodenum is the L-shaped segment of the small bowel, cradling the pancreas to the immediate right. **(b)** The pancreas is pointed out by the forceps tip.

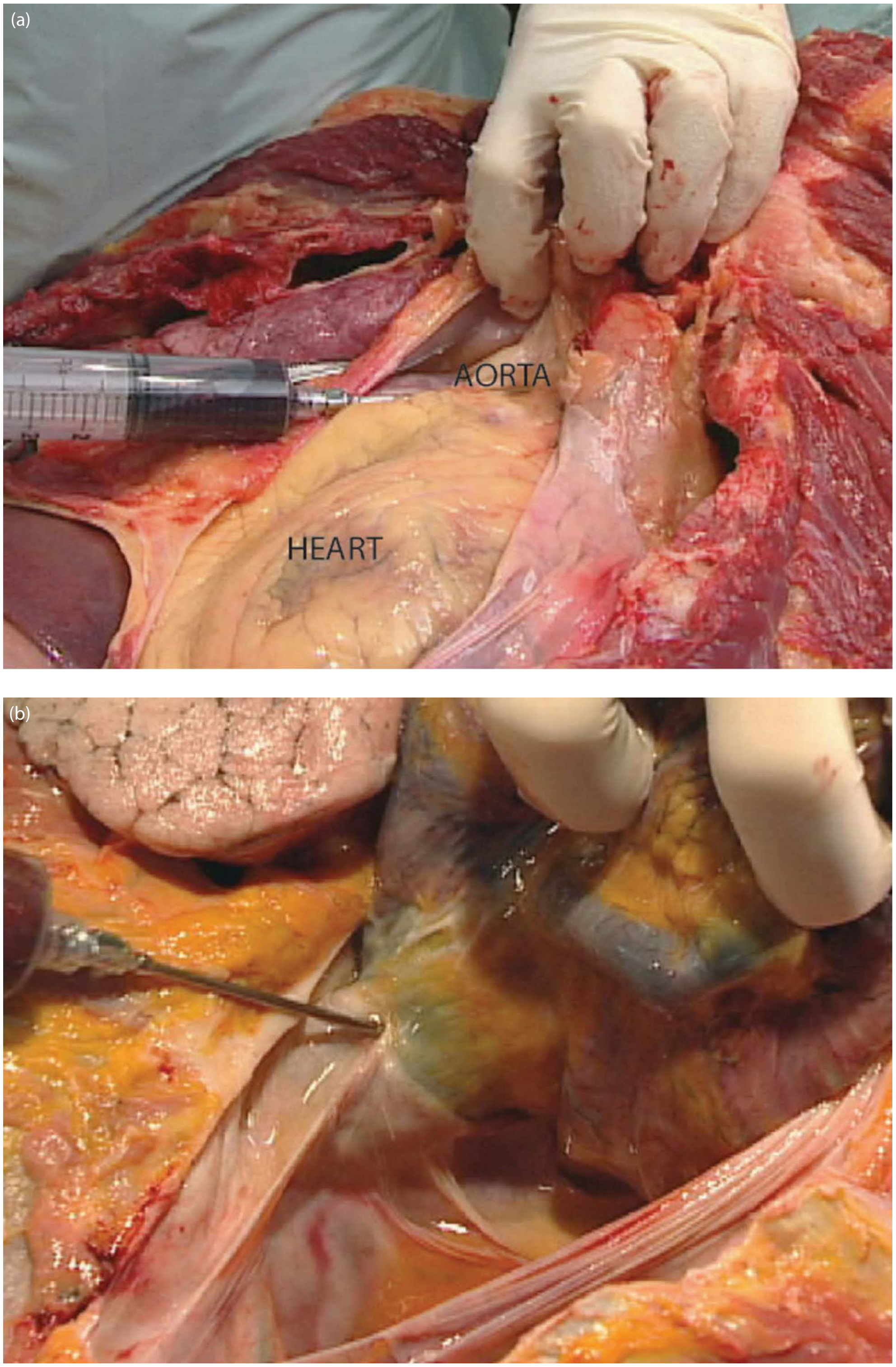


Figure 6.37 (a) Taking blood from the aorta. Routinely, blood is removed from the aorta. **(b) Taking blood from the inferior vena cava.** Blood screening is usually preferable when the concentration of a specific drug must be known (e.g., alcohol or carbon monoxide).

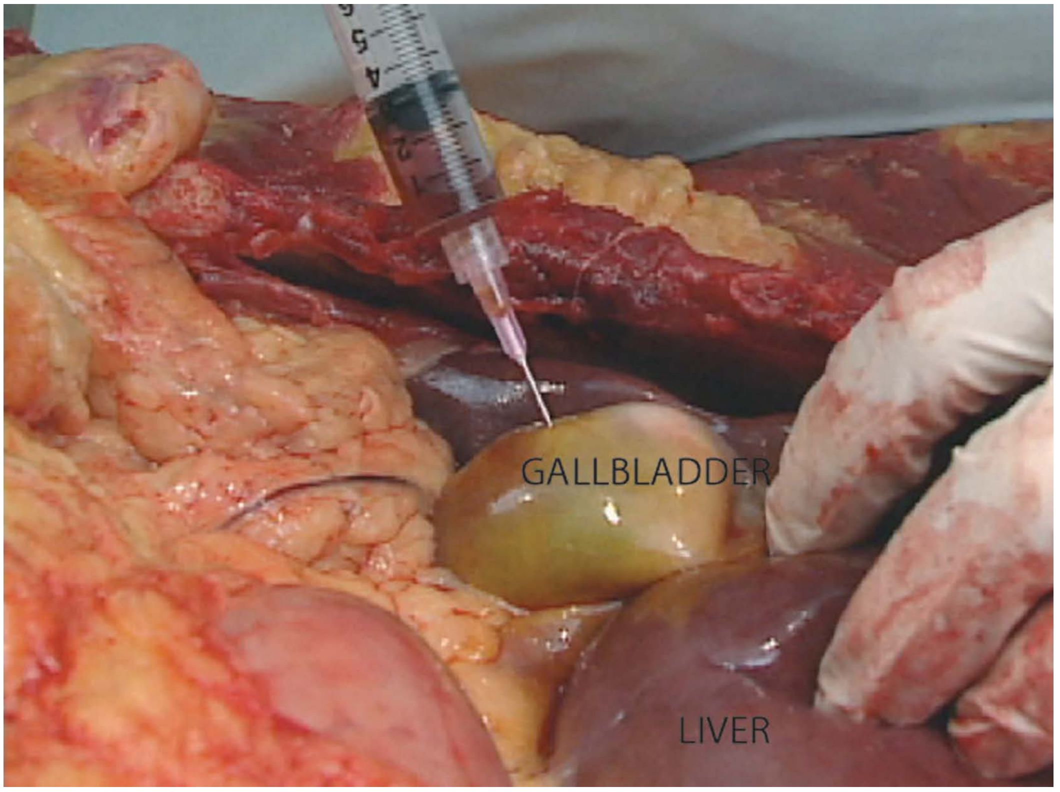


Figure 6.38 Obtaining bile from the gallbladder. Cocaine and other narcotics concentrate in the bile. Because cocaine has a short half-life in the blood, testing bile can confirm the presence of cocaine in cases where cocaine abuse is suspected and blood levels are negative.

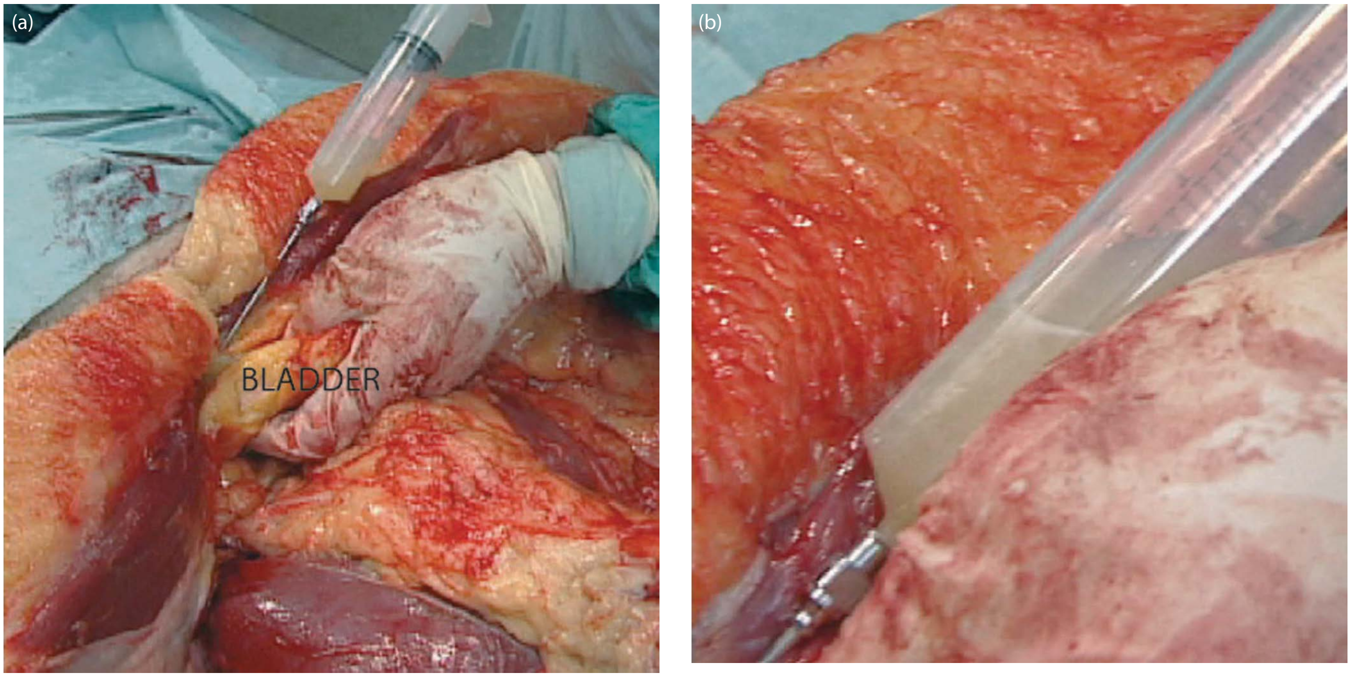


Figure 6.39 (a and b) Removing urine from the bladder. At least 7 cc of blood is preferred when screening for most drugs, toxins, and poisons. Urine is the preferred body fluid when screening for the most commonly abused drugs. When testing for the presence of some drugs and toxins, tissues such as brain, muscle, fat, hair, liver, kidney, bone, and nails are preferred. For example, arsenic is best found in the hair and nails.

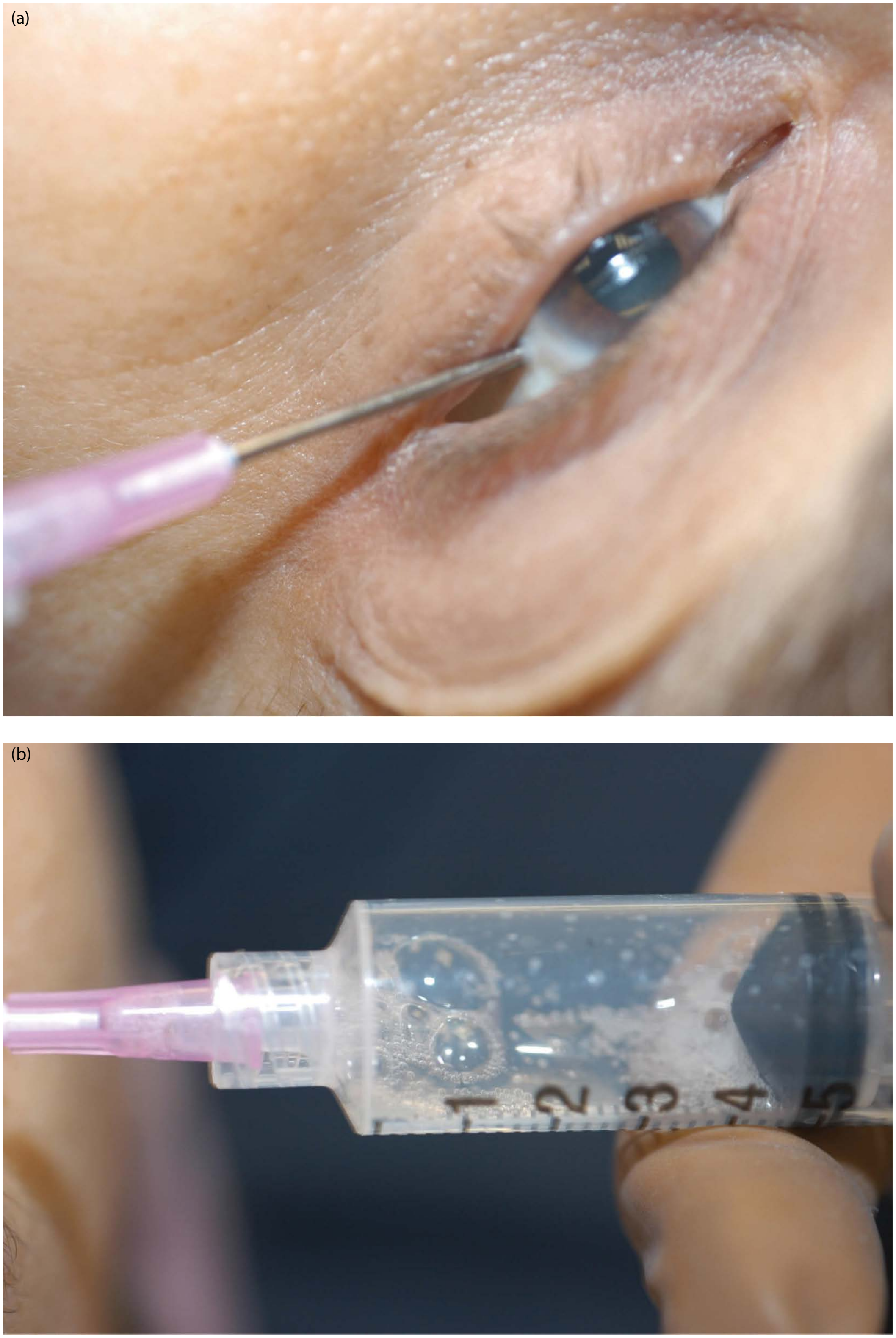


Figure 6.40 (a and b) Obtaining vitreous humor from the eye. Vitreous humor, or clear liquid fluid in the eye, is obtained routinely. Since the vitreous humor tends to concentrate drugs and other analytes, testing is useful in a number of cases. For example, blood glucose is not reliable postmortem. A very high postmortem vitreous glucose can aid in the diagnosis of diabetic hyperglycemia (high blood sugar).

CHAPTER 7

ORGAN AND TISSUE REMOVAL

In the Virchow autopsy method, the organs are removed one after another in an organized and logical fashion (i.e., the neck organs are removed after the viscera to negate the artefactual appearance of hemorrhage often produced by congestion). Other organ removal methods include the Gohn, Letulle, or modified Rokitansky methods, in which the organs are removed en bloc (all together). This type of removal allows the internal viscera to be examined while they are still connected together. Some pathologists always remove organs en bloc. The author has found the Gohn method to be useful when examining infants with multiple cardiac and other birth defects. There is no right or wrong method of dissection; the aim is simply to perform a complete autopsy and to provide a detailed description of that autopsy.

The reader should follow the photographs in Figures 7.1 through 7.56 to see the steps of organ and tissue removal. (See Videos 7.1 through 7.3.)

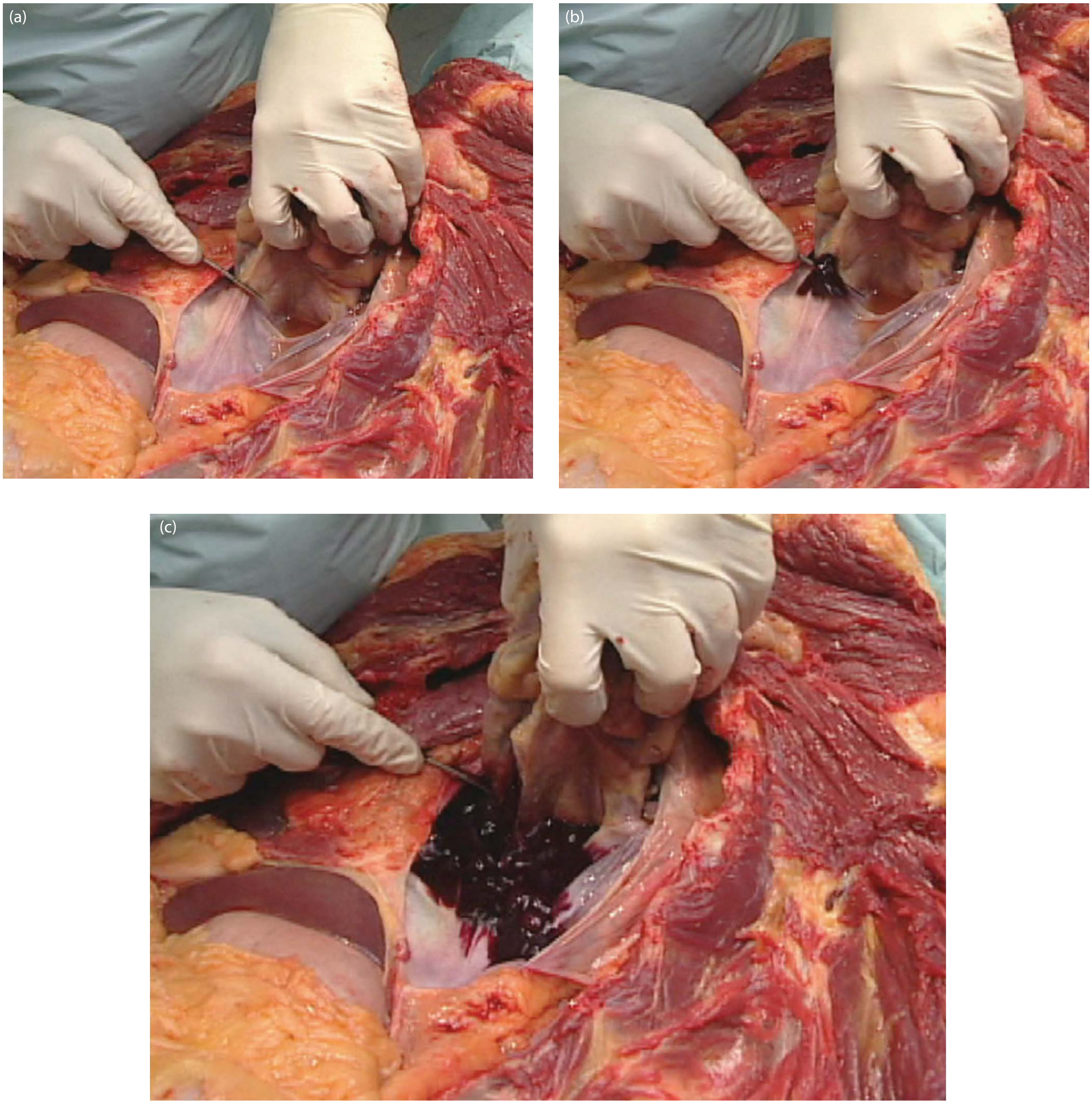


Figure 7.1 (a–c) Heart removal, cutting the inferior vena cava. The inferior vena cava is cut, as are the pulmonary veins, pulmonary arteries, and aorta. The heart is held in the left hand in these figures. Blood flows from the cut vessels if the blood is not clotted, decomposed, or mostly absent from the body. In cases of severe hemorrhage, there is a notable absence of blood at this moment of the autopsy.

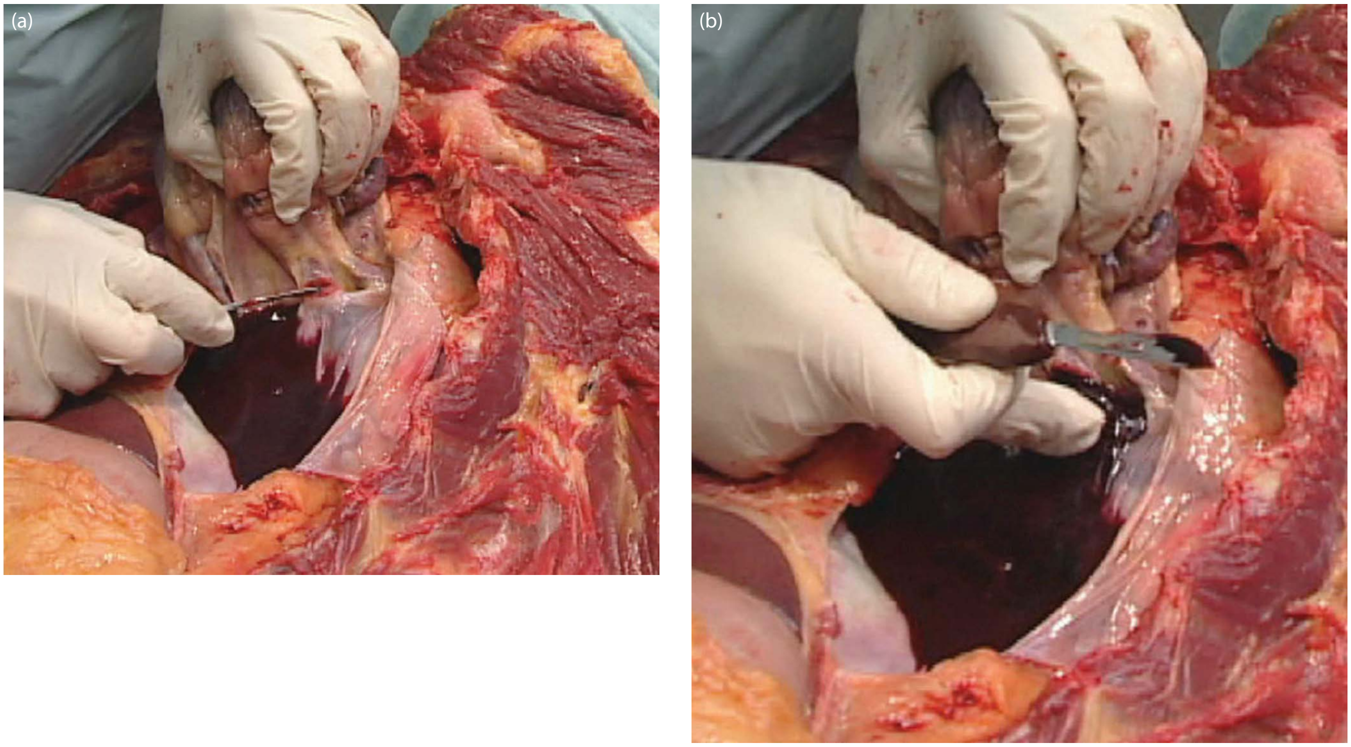


Figure 7.2 (a) Cutting the pulmonary artery. The left pulmonary artery is cut, as is the left pulmonary vein. **(b) Checking for pulmonary embolus.** The pulmonary artery is checked for a clot (thromboembolus).

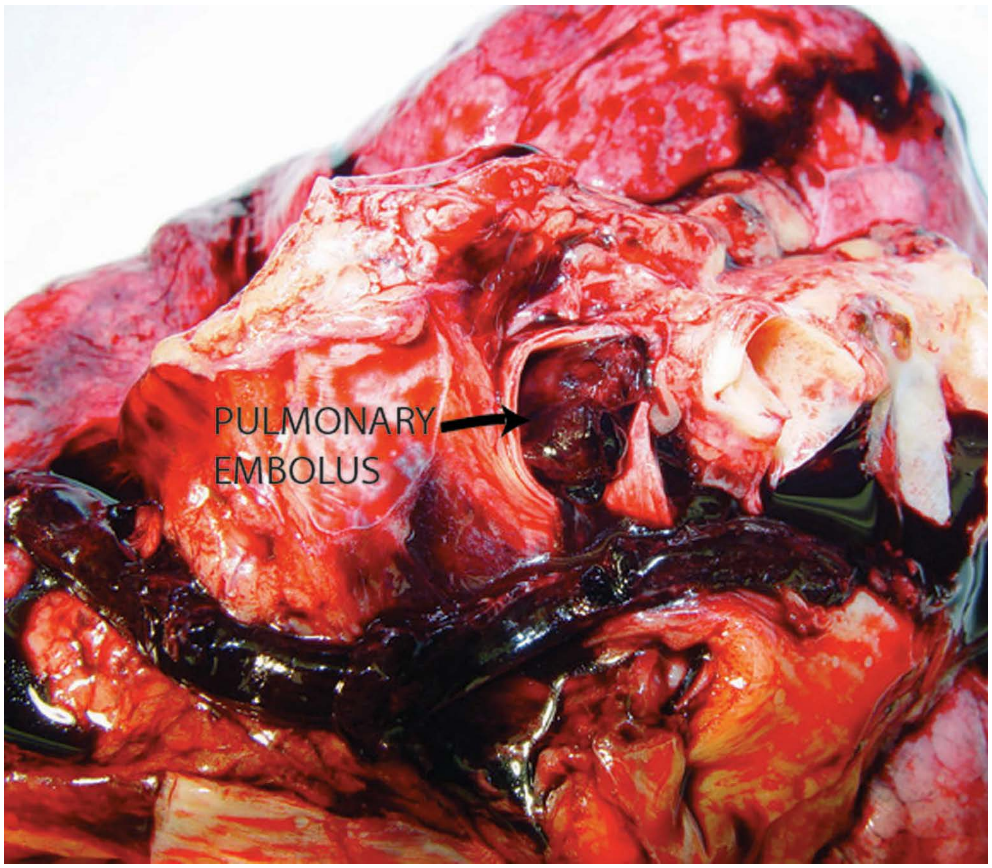


Figure 7.3 Pulmonary embolus. The long blood clot depicted was taken from the inferior vena cava. A large pulmonary embolus is seen in the pulmonary artery as well. These clots (emboli) can move up from the lower leg veins or, less commonly, from the pelvis or upper arm veins to the right heart, and then out to the pulmonary arteries. If these thromboemboli are large enough, they can cause immediate cardiac arrest.

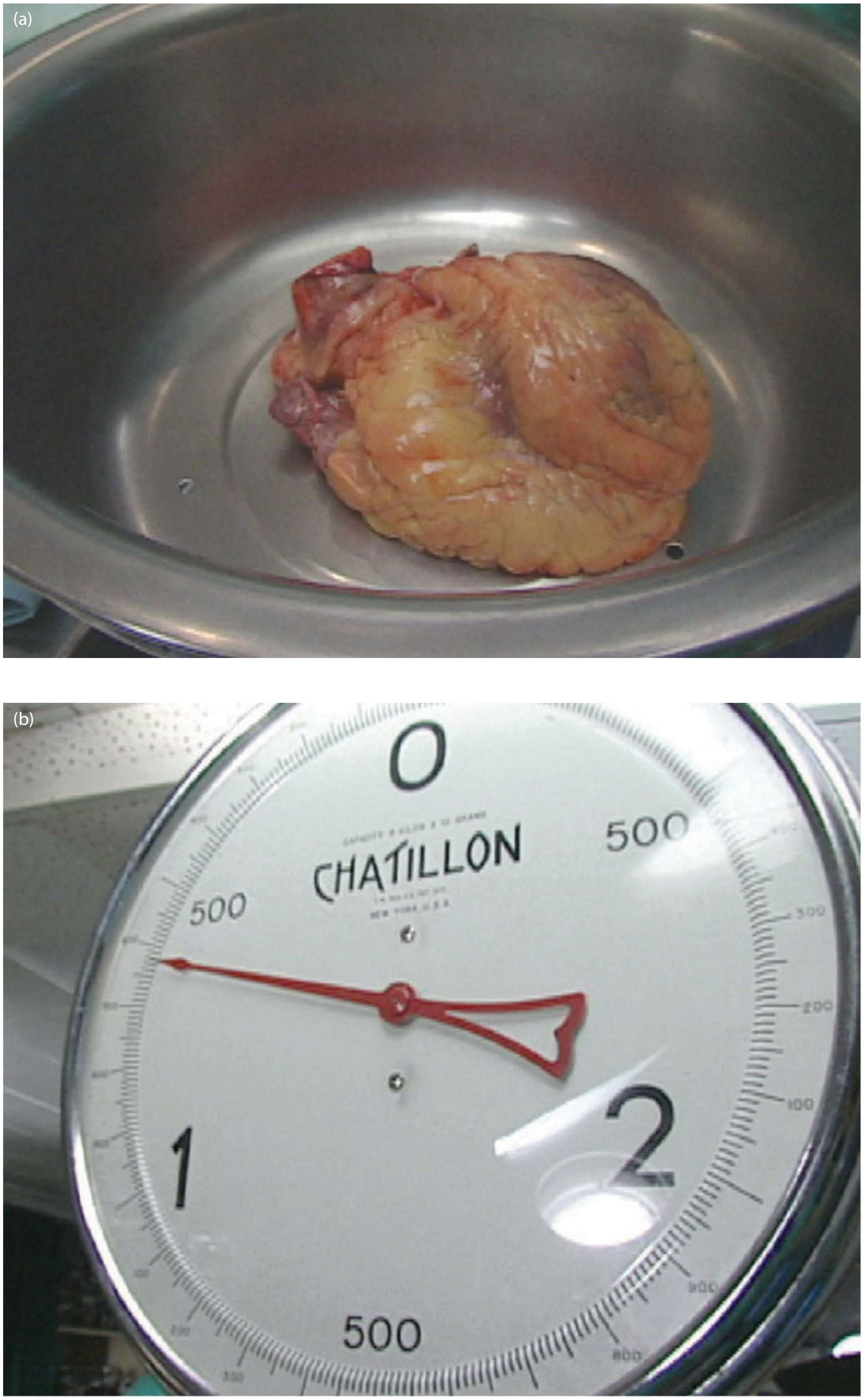


Figure 7.4 (a and b) Weighing the heart. The heart, like all organs, is weighed. Increased weight of the heart can indicate hypertensive heart disease or numerous other conditions that cause heart failure, such as cardiomyopathy. The heart is a specialized muscle that increases in size and weight as more work is required of it. High blood pressure causes the heart to increase in weight and thickness because of the increased pressure that the heart must maintain. The average heart weighs approximately 350 g in a 190-lb man. A hypertensive heart might weigh more than 500 g. This particular heart weighs approximately 620 g, due to hypertensive heart disease.

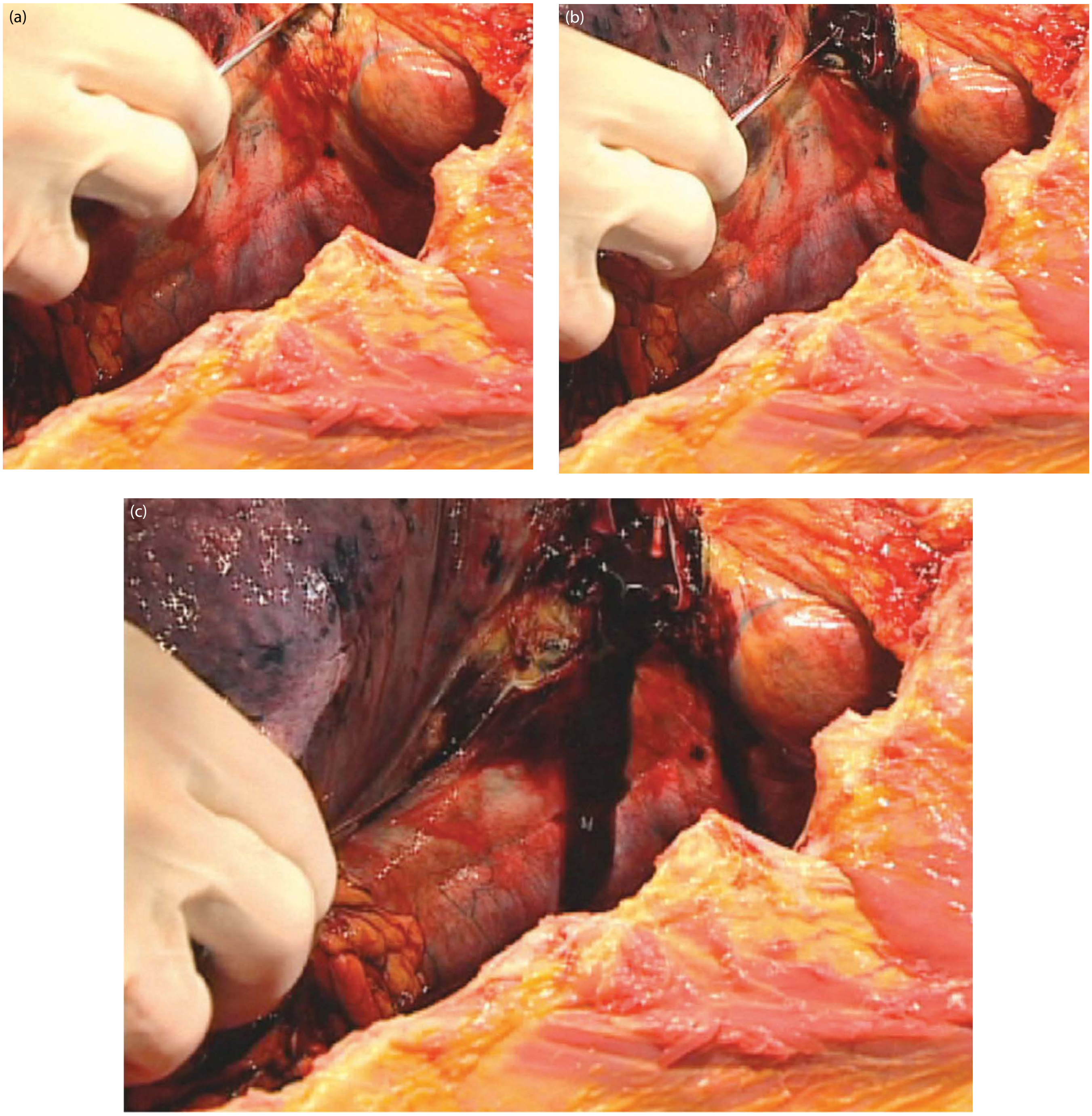


Figure 7.5 (a–c) Excision of the lungs. The lungs are removed at the hilum, or center of attachment.

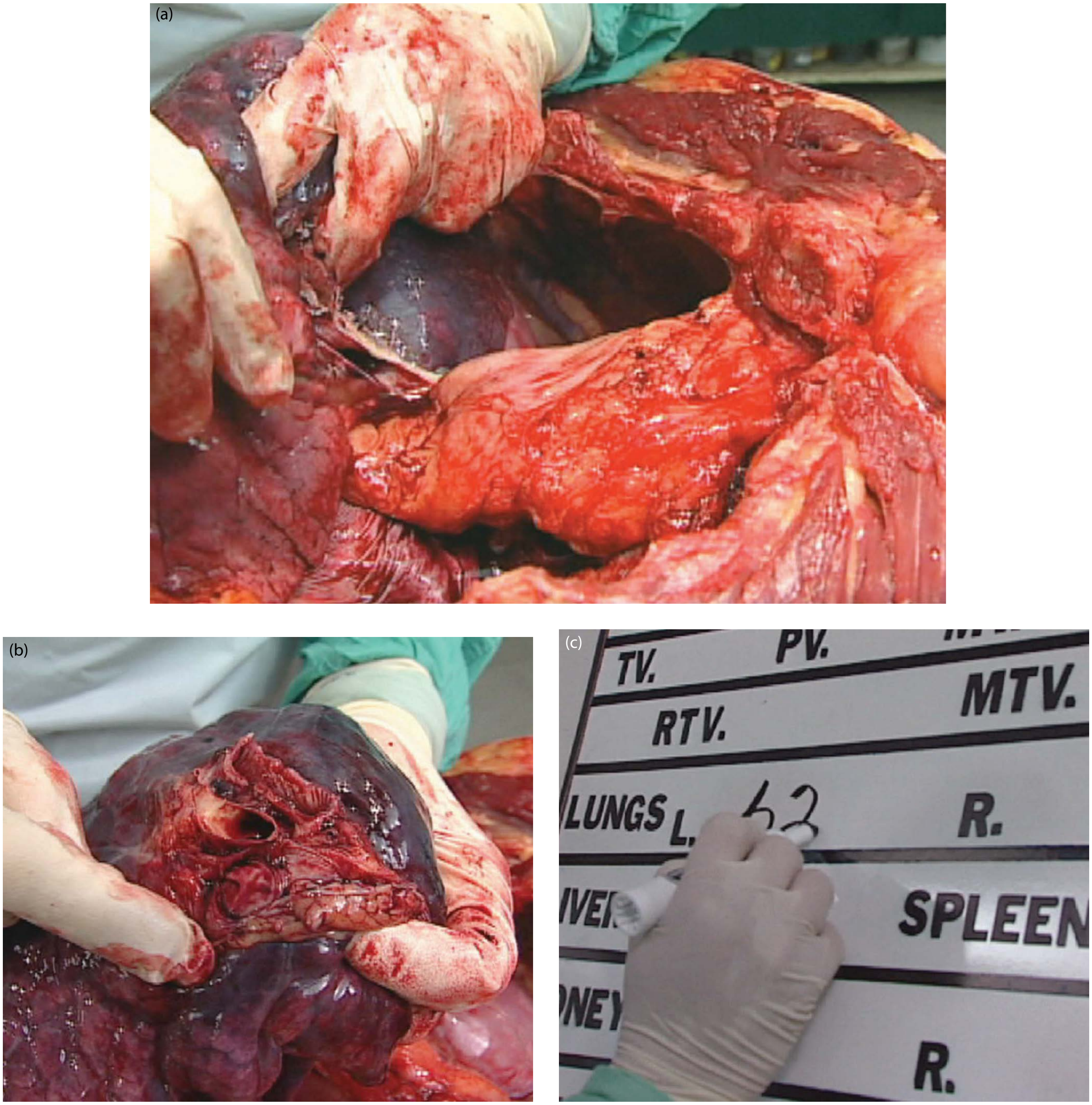


Figure 7.6 (a–c) Examination of the hilum. As this right lung is removed, the hilum is quickly examined for tumors or infection. The lung is weighed. Heavy lungs are commonly seen in pneumonia and heart failure (associated with pulmonary edema).

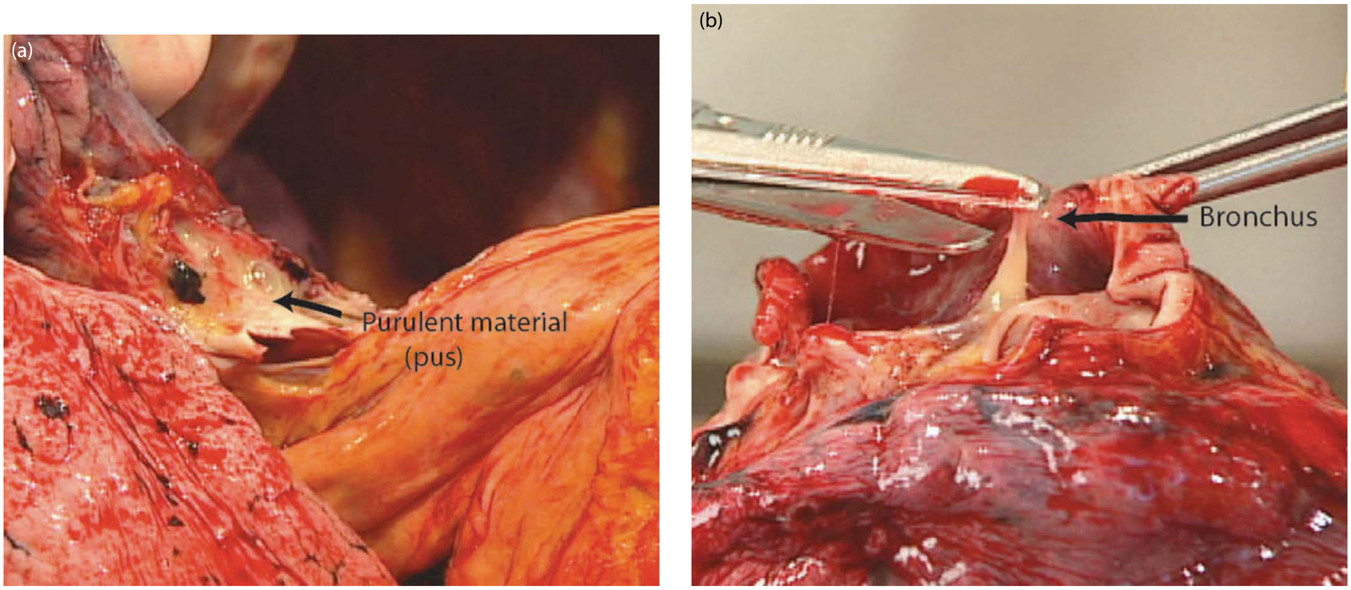


Figure 7.7 Bronchial pneumonia. (a) Examination of this hilum shows pus in the bronchus bubbling through the bronchial artery. **(b)** The pus can be seen at the tip of the scissors. The pus is a sign of bronchopneumonia.

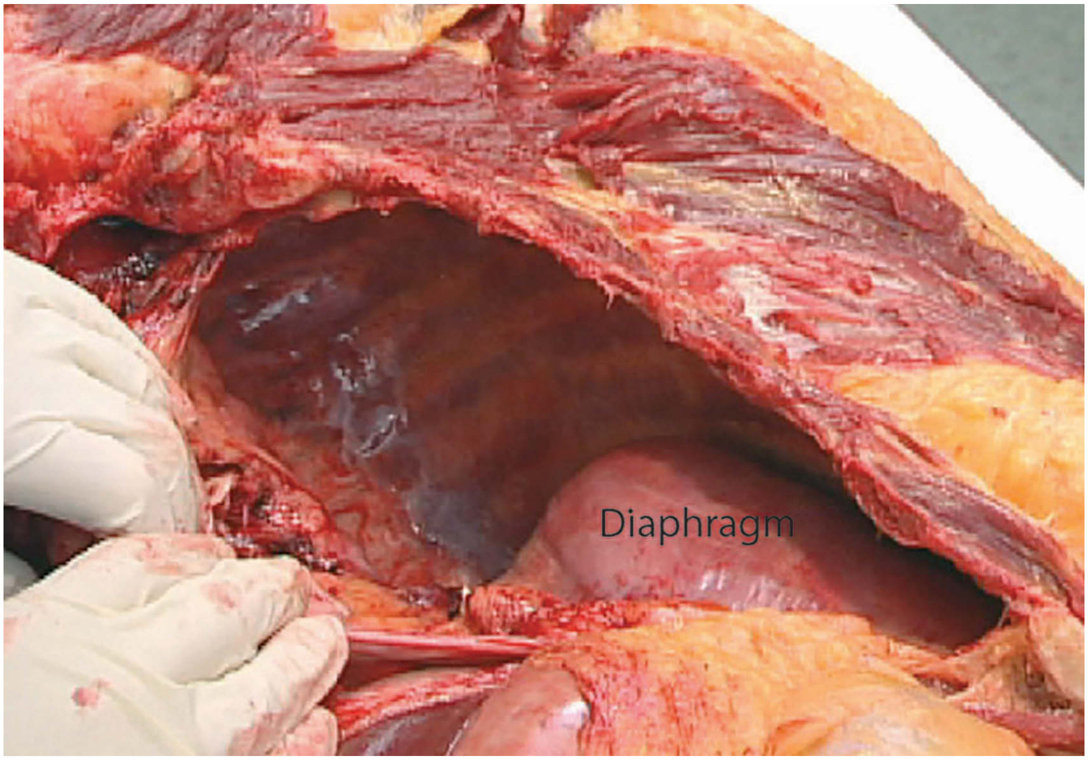


Figure 7.8 Chest cavity examination. The chest cavity and ribs are examined for tumors, rib fractures, and contusions, among other conditions. The diaphragm is the dome-shaped structure in the lower center of the picture.

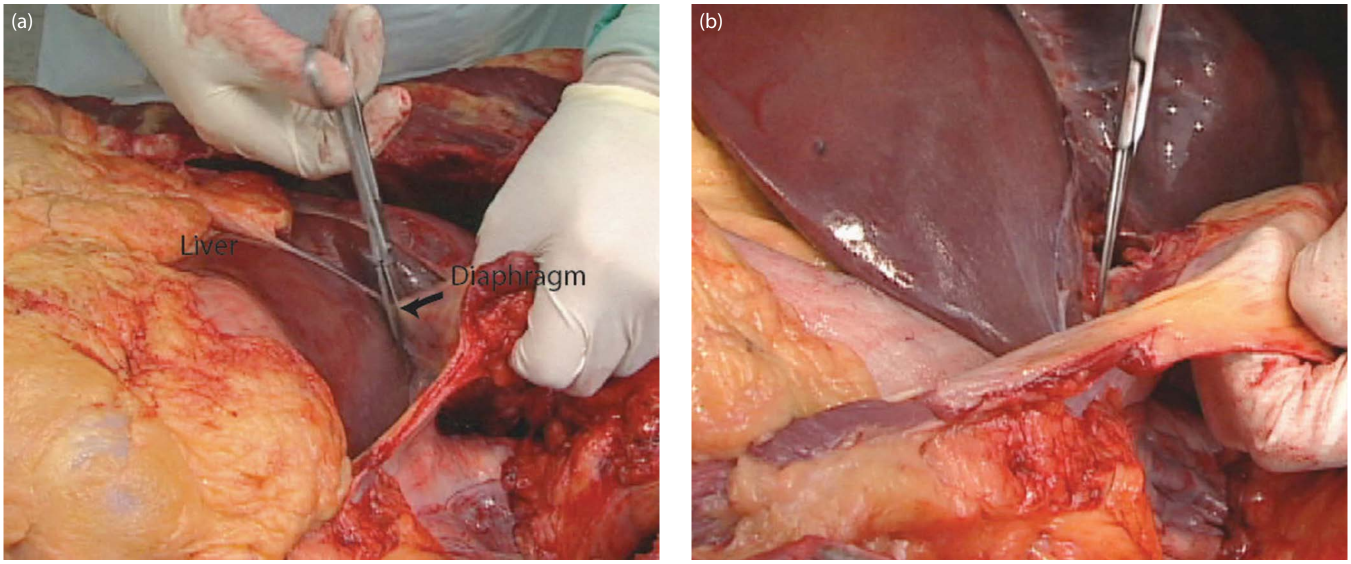


Figure 7.9 (a and b) Freeing the liver from the diaphragm. The liver is freed from the diaphragm, ligaments, and other attachments.

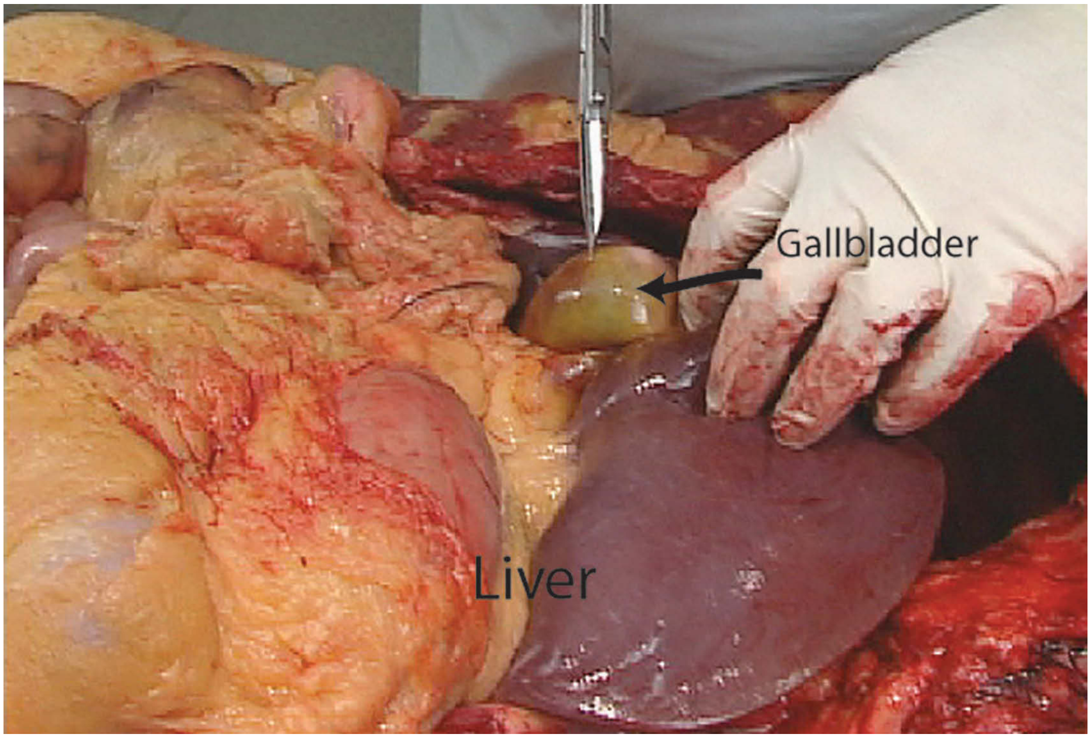


Figure 7.10 Liver and gallbladder. The gallbladder is seen in situ. The diaphragm has been cut away and the liver is turned up toward the head. The gallbladder is removed with the liver.

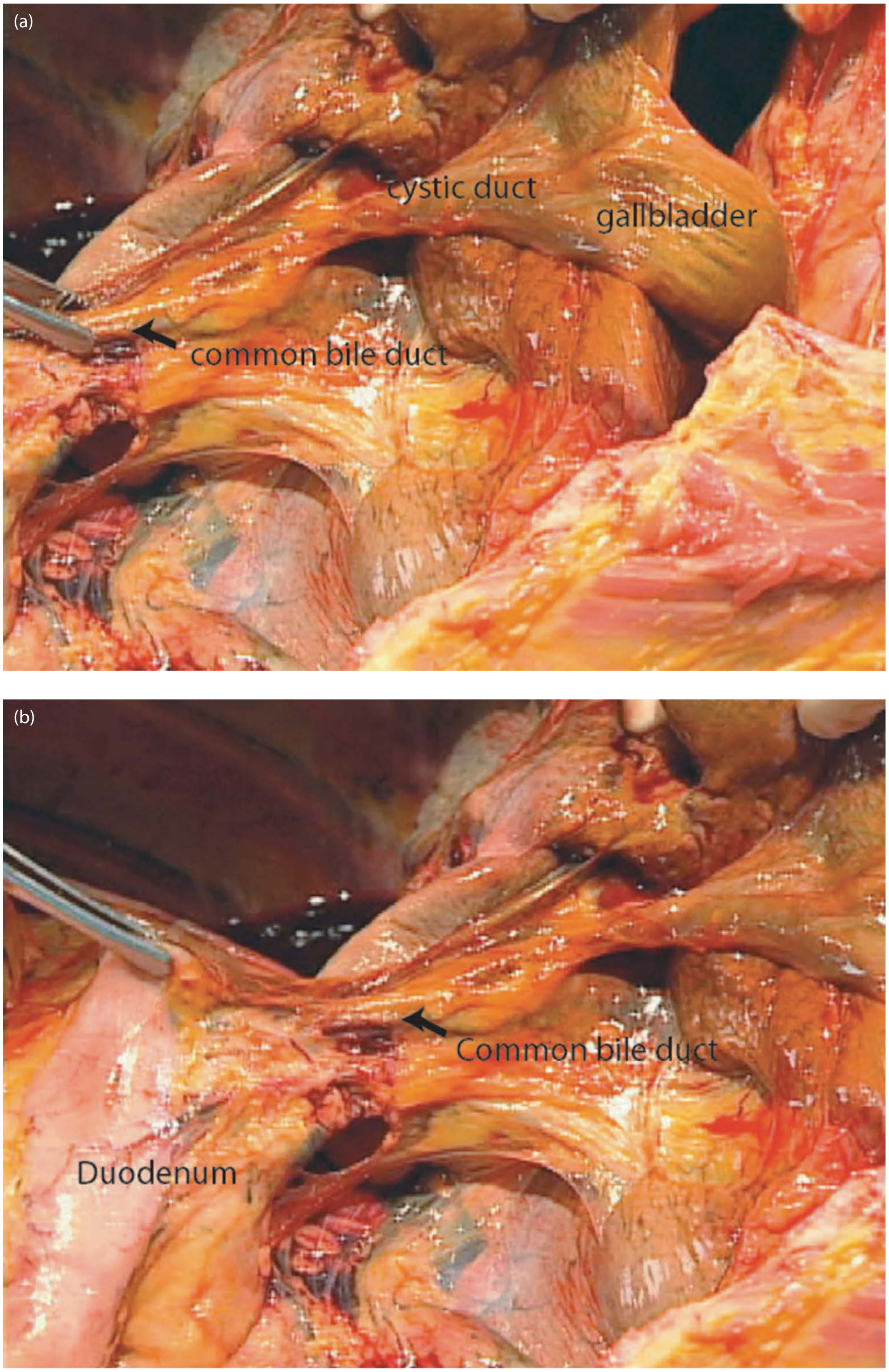


Figure 7.11 (a–d) Common bile duct and duodenum. The common bile duct is displayed as it empties bile into the duodenum. In **(b)**, the duodenum is held up by the forceps. The common duct is cut and examined for stones as well. Gallstones or other stones can plug up the duct, preventing bile from draining from the liver and resulting in jaundice in the patient. (*Continued*)

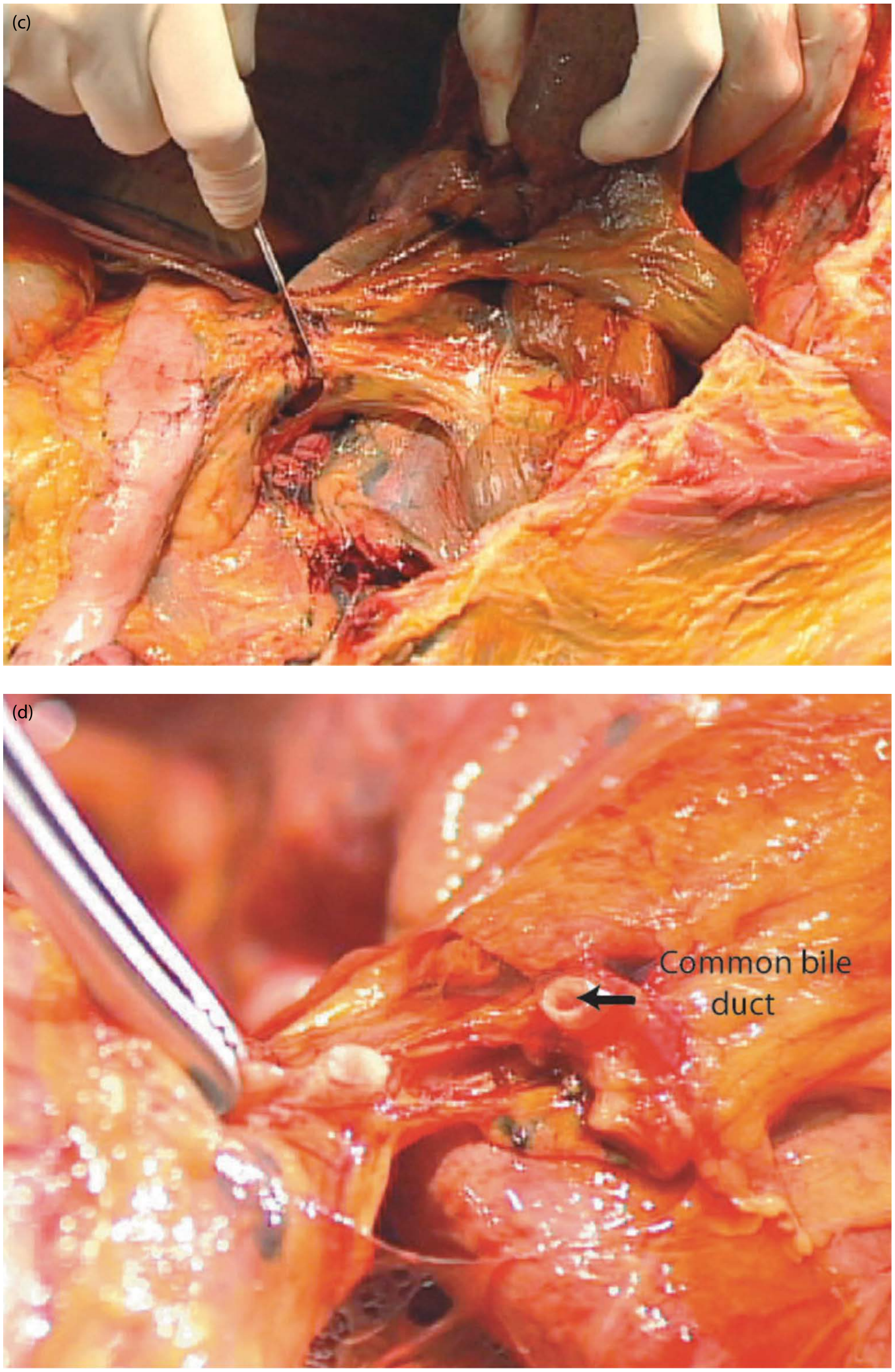


Figure 7.11 (*Continued*) (a–d) Common bile duct and duodenum. The common bile duct is displayed as it empties bile into the duodenum. In **(b)**, the duodenum is held up by the forceps. The common duct is cut and examined for stones as well. Gallstones or other stones can plug up the duct, preventing bile from draining from the liver and resulting in jaundice in the patient.

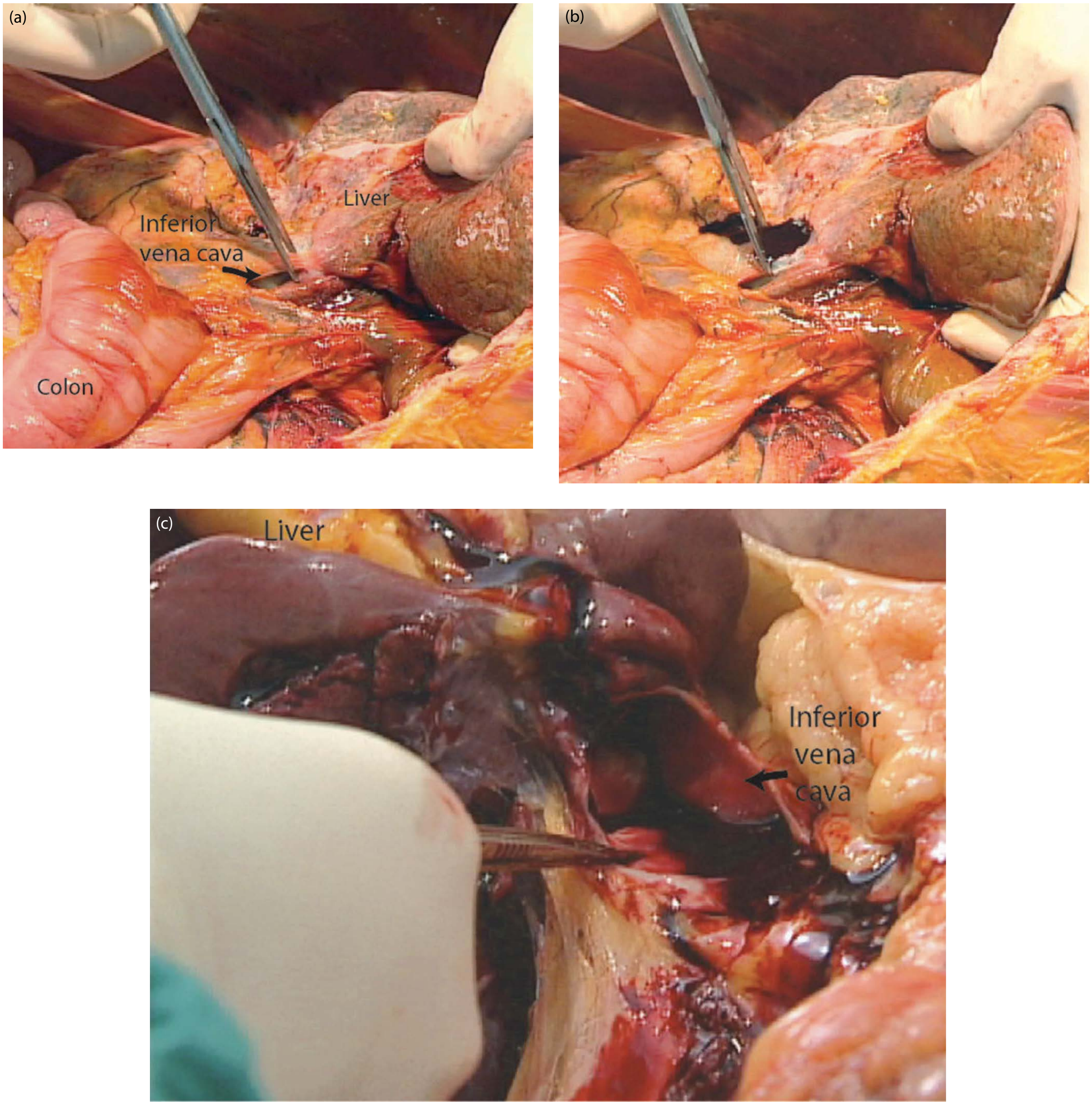


Figure 7.12 Cutting the inferior vena cava. (a and b) The inferior vena cava is cut as it enters the dorsal surface of the liver. **(c)** This image shows the large diameter of the inferior vena cava when opened.

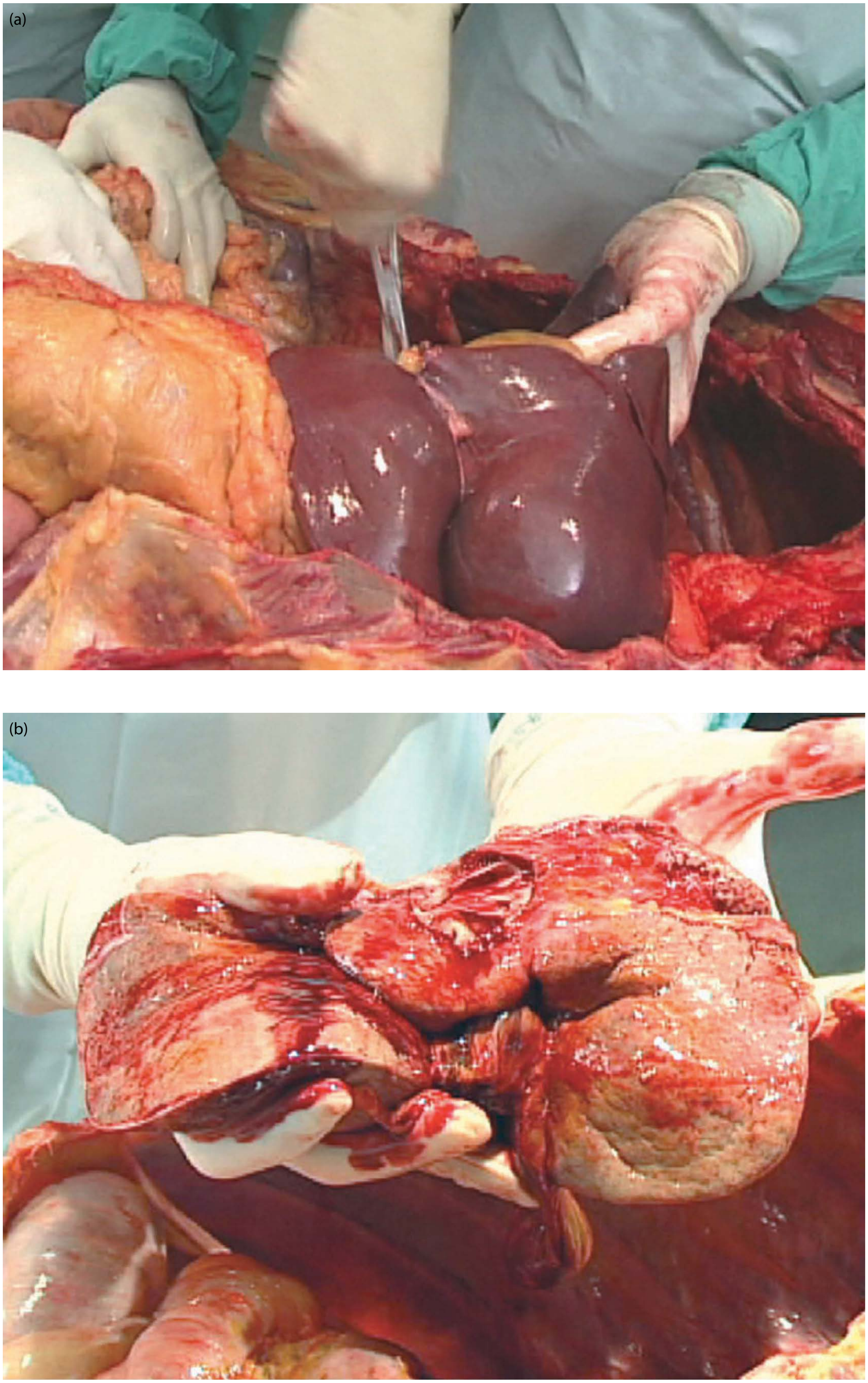


Figure 7.13 (a and b) Removing the liver. Once the liver is completely cut away, it is lifted out of the body for weighing. Those who see the liver for the first time are astonished at its size and weight. The average liver weighs approximately 1930 g, or approximately 4.5 lb, in a 170-lb man.

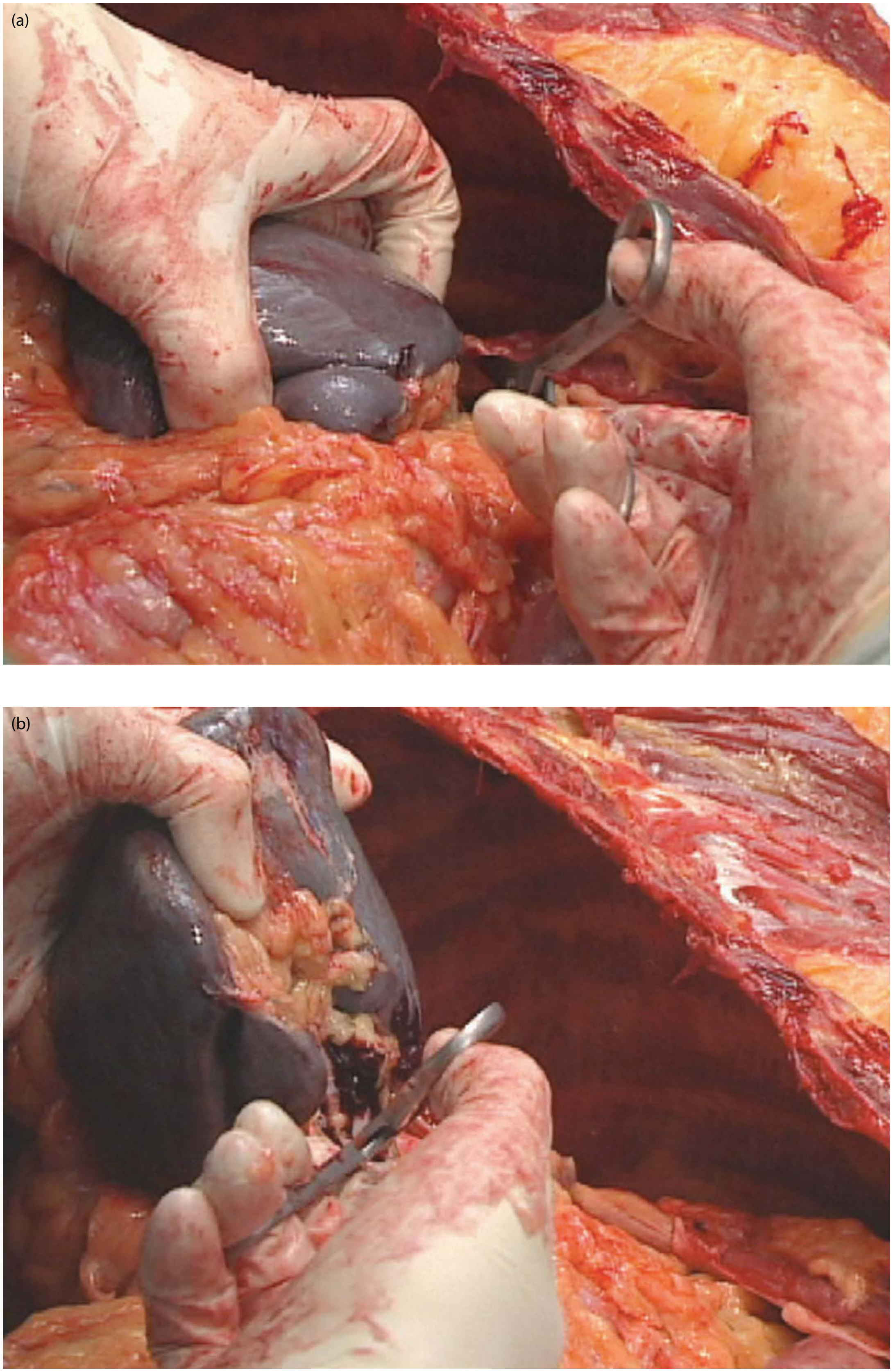


Figure 7.14 (a and b) Removing the spleen. The spleen is removed by cutting the vessels away from the hilum, checking carefully for lacerations, because the capsule (covering) of the spleen can be easily torn on removal.

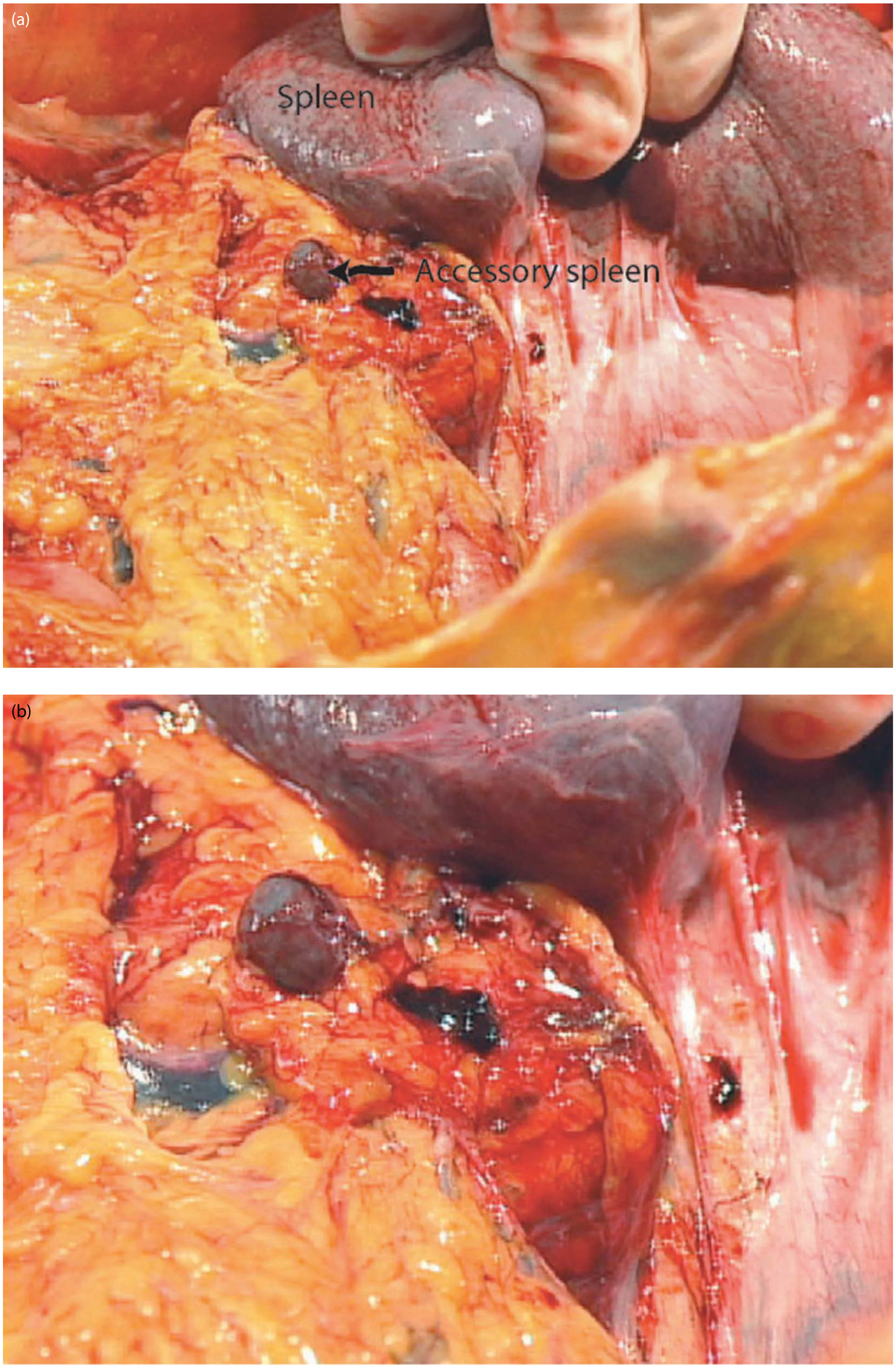


Figure 7.15 (a and b) Accessory spleen. Adjacent to this spleen is a small accessory spleen. Accessory spleens can become quite large if the main spleen is removed. This can be problematic in a condition called hypersplenism, in which the spleen pathologically destroys red blood cells. The accessory spleen, if not removed, can enlarge and cause the hypersplenism to return.

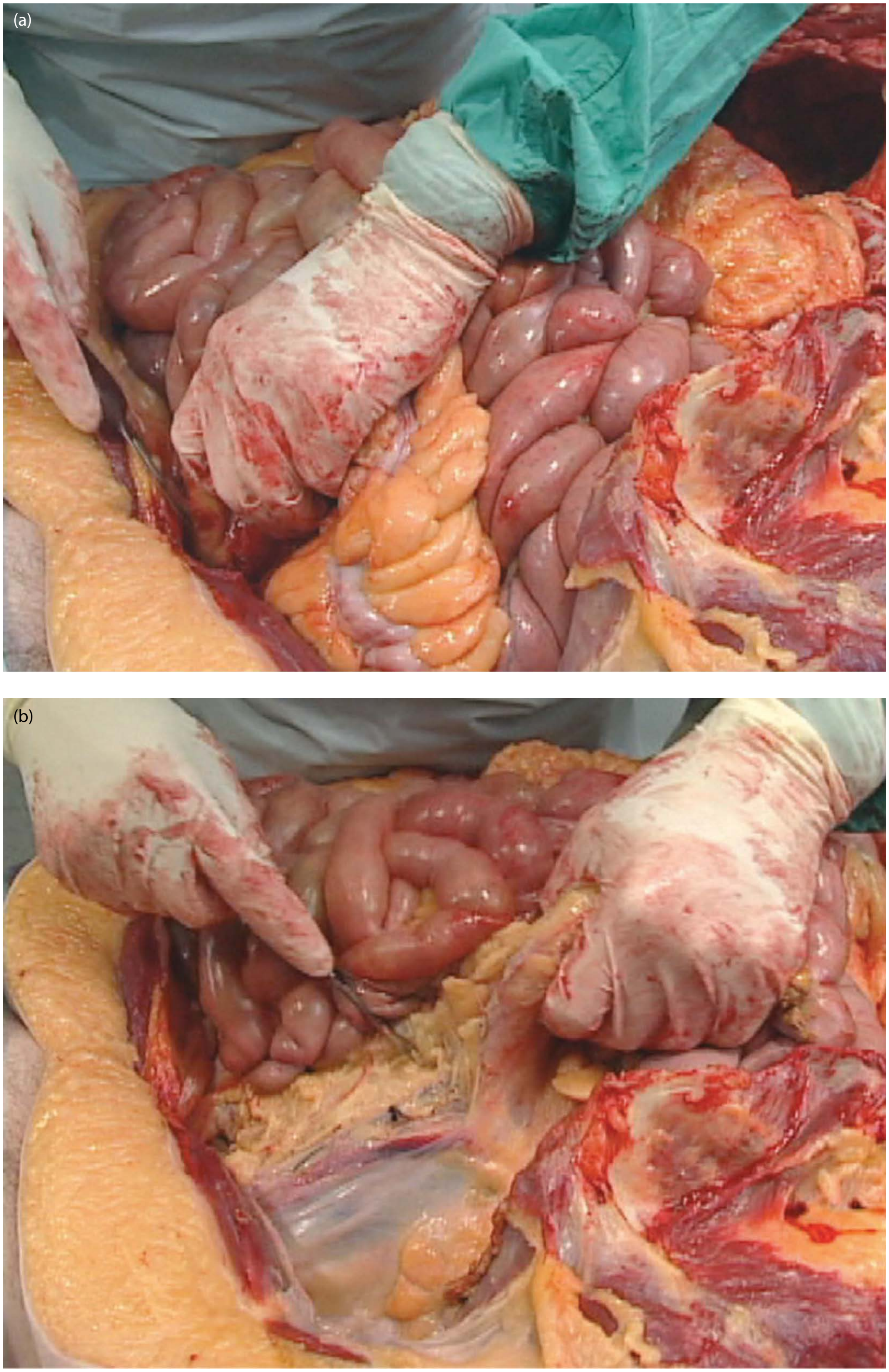


Figure 7.16 (a and b) Bowel excision. In this removal method, the excision starts at the rectum and progresses upward toward the sigmoid colon in the left part of the abdomen.

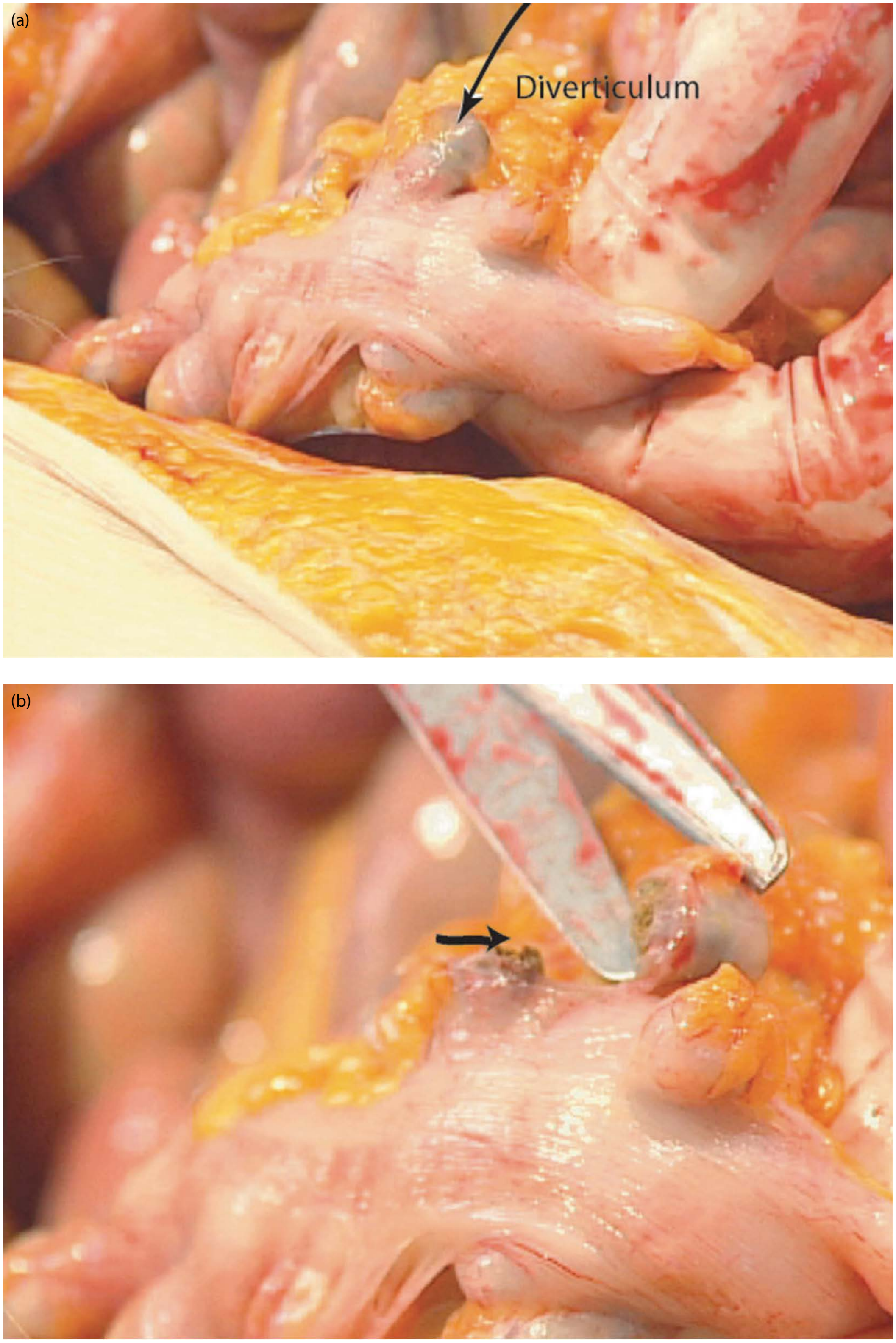


Figure 7.17 Diverticuli of the sigmoid colon. (a) The sigmoid colon is prone to forming diverticuli, often seen in middle-aged to older patients. In this condition, the mucosa herniates through weak points in the muscular colon wall. **(b)** Fecal matter, seen on cutting (arrow), can plug up these diverticuli and cause inflammation (diverticulitis).

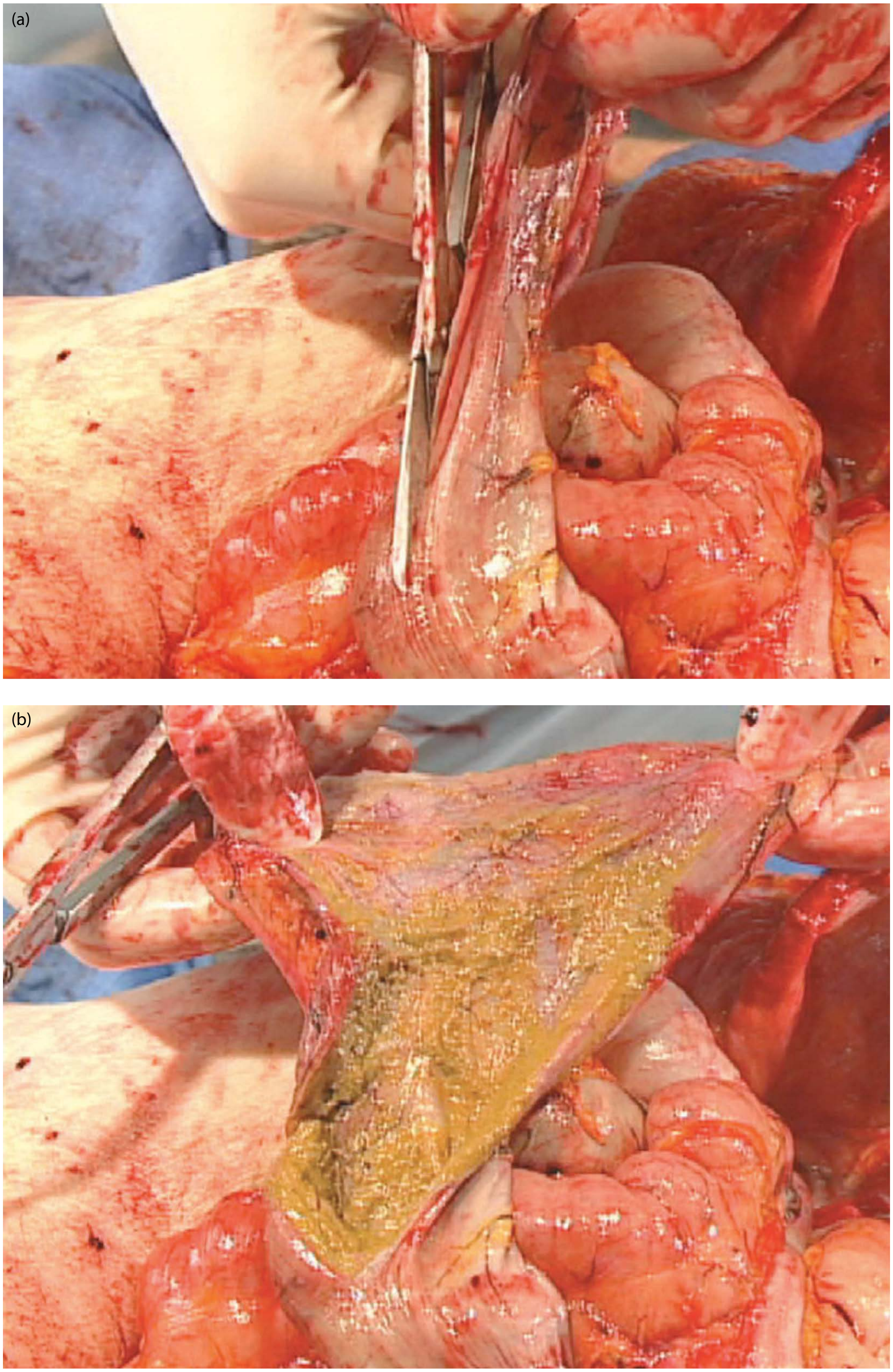


Figure 7.18 (a and b) Opening or "running" the bowel. The bowel is opened completely and examined for tumors, diverticuli, and other lesions.

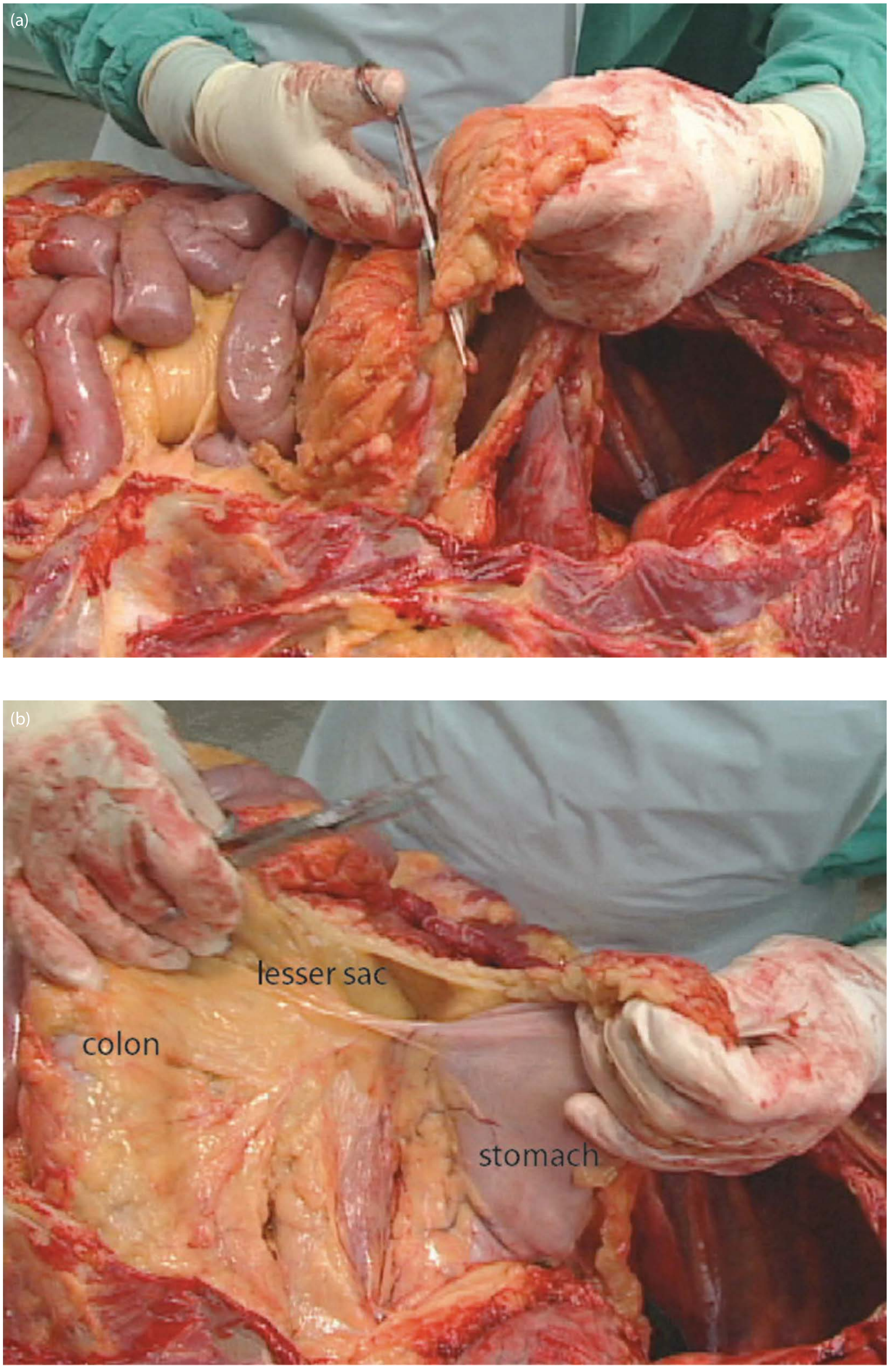


Figure 7.19 (a and b) Cutting the gastro-colic ligament. The gastro-colic ligament, between the stomach and transverse colon, is cut, opening the lesser sac.

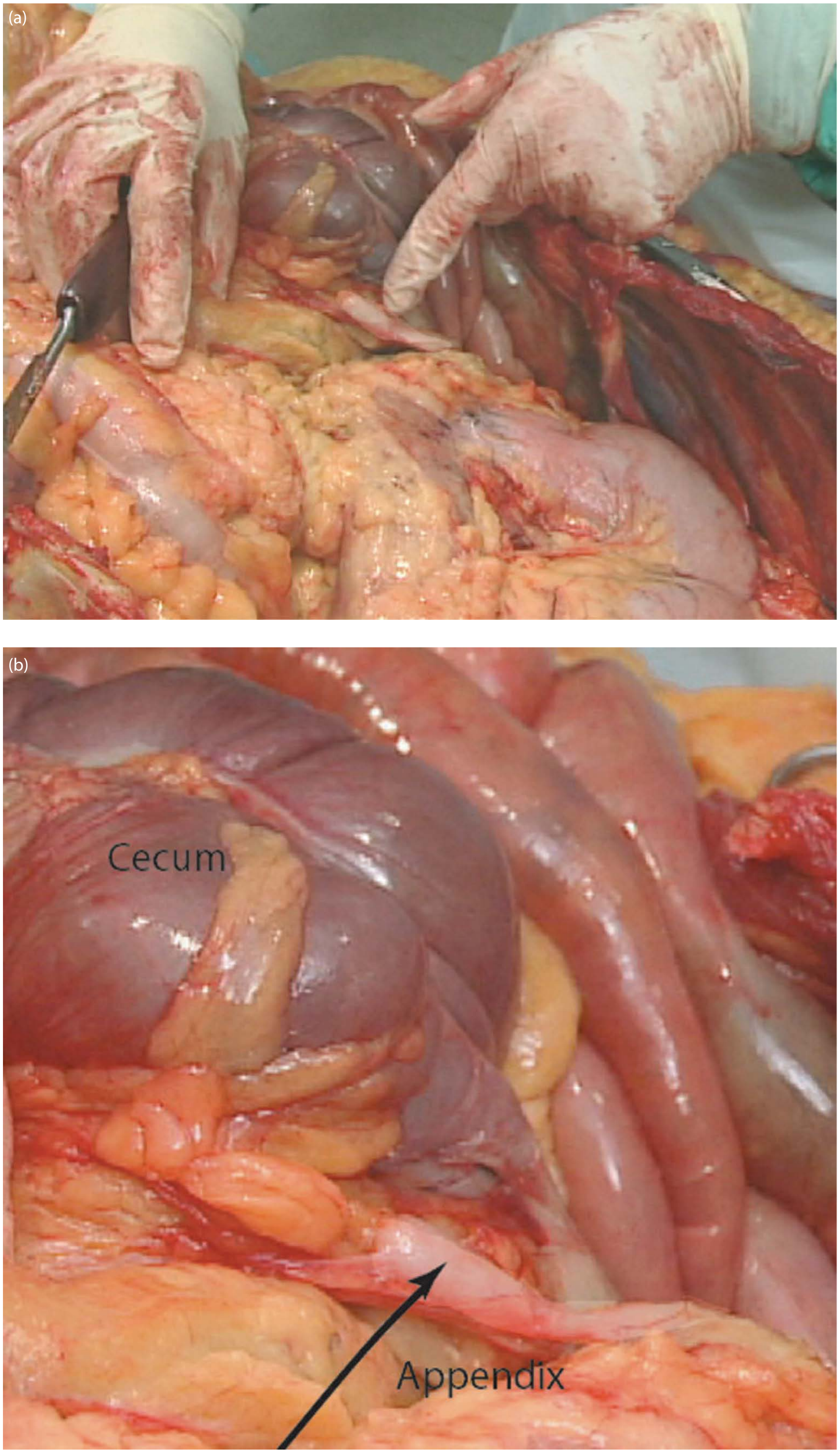


Figure 7.20 (a and b) Cecum and appendix. The cecum and the adjacent appendix are seen in the right lower quadrant of the abdomen, just below the finger. There is no evidence of inflammation (appendicitis). The presence or absence of an appendix and accompanying scar can be helpful in identification.

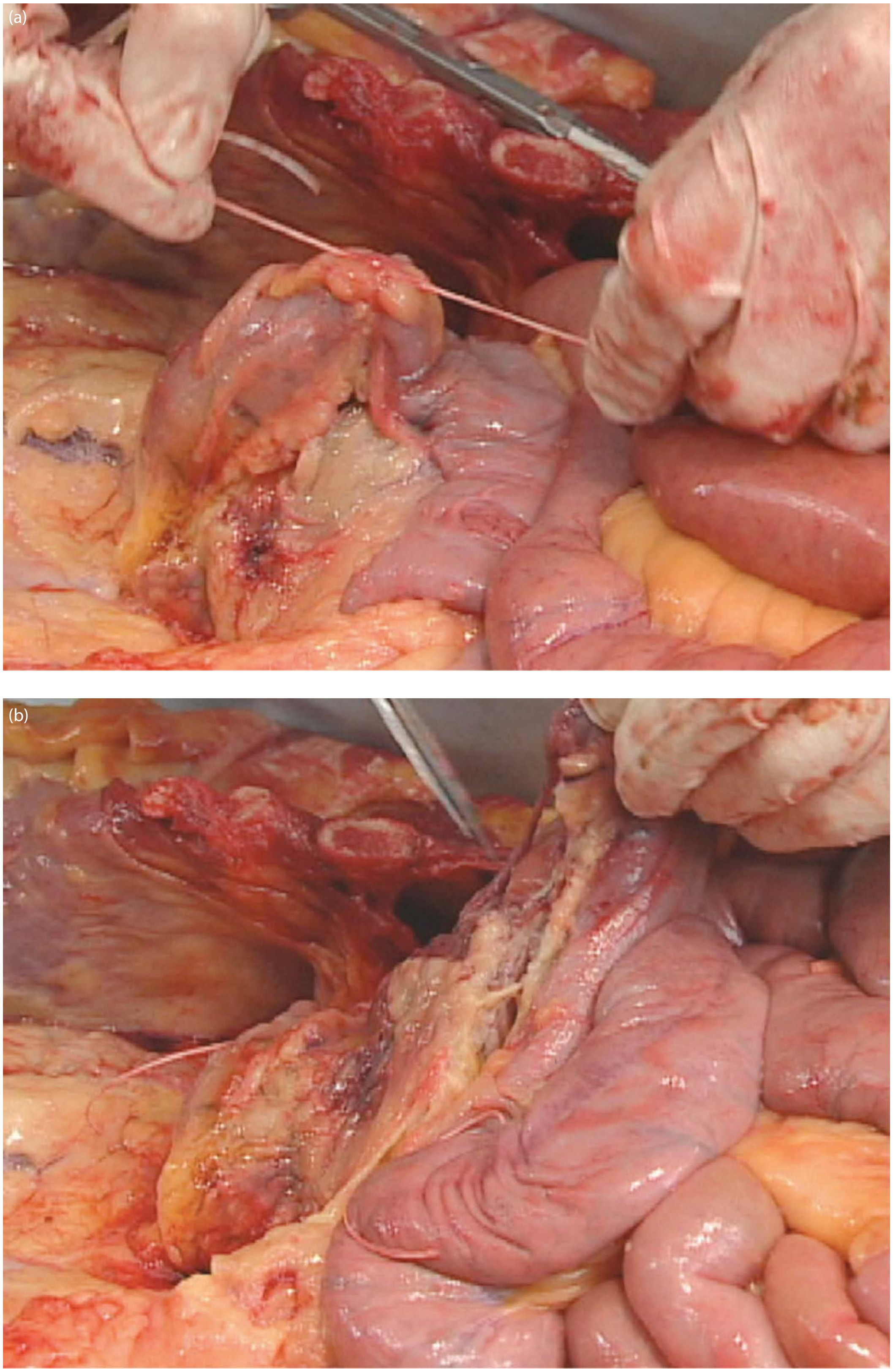


Figure 7.21 (a and b) Tying and cutting of the duodenum. The duodenum is tied. This is done to prevent gastric contents from leaking out when the duodenum is cut for removal.

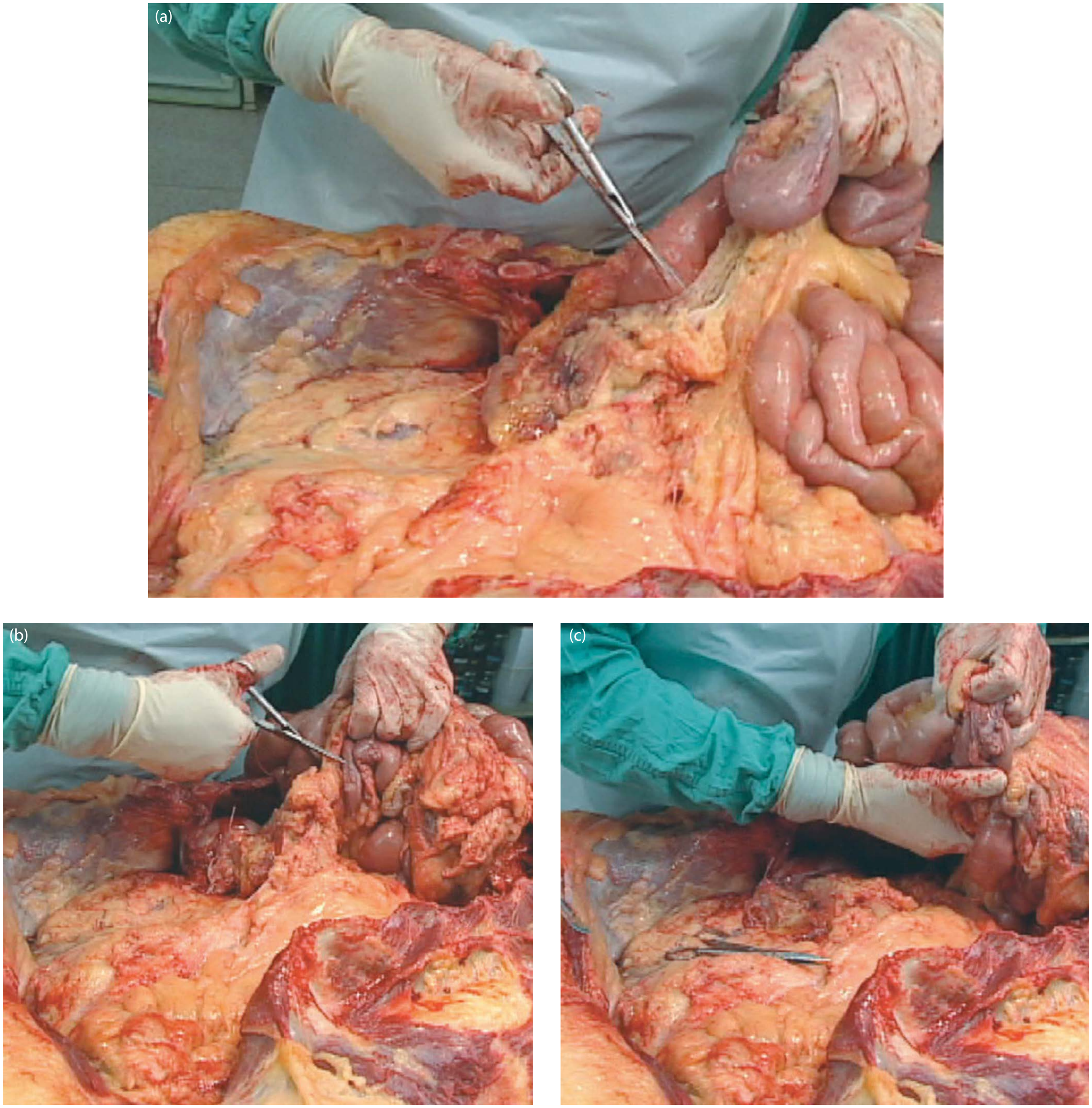


Figure 7.22 (a–c) Removal of the small and large bowels. The small and large bowels are removed as the mesentery is cut. Traction is applied to the bowels as the soft tissue is cut.

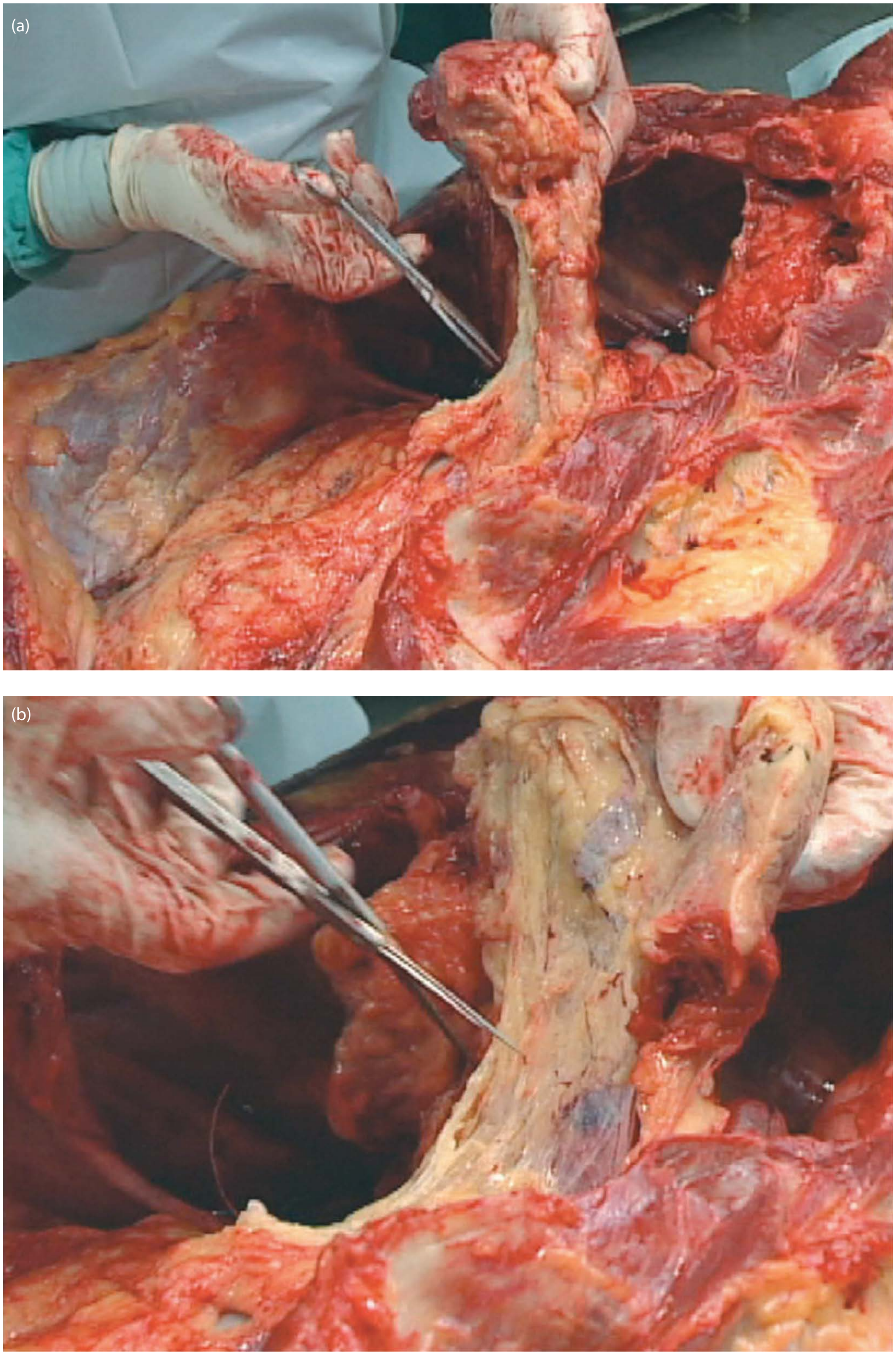


Figure 7.23 (a and b) Excising the pancreas and duodenum. The pancreas and duodenum are held in the left hand as the soft tissue is cut by the right hand.

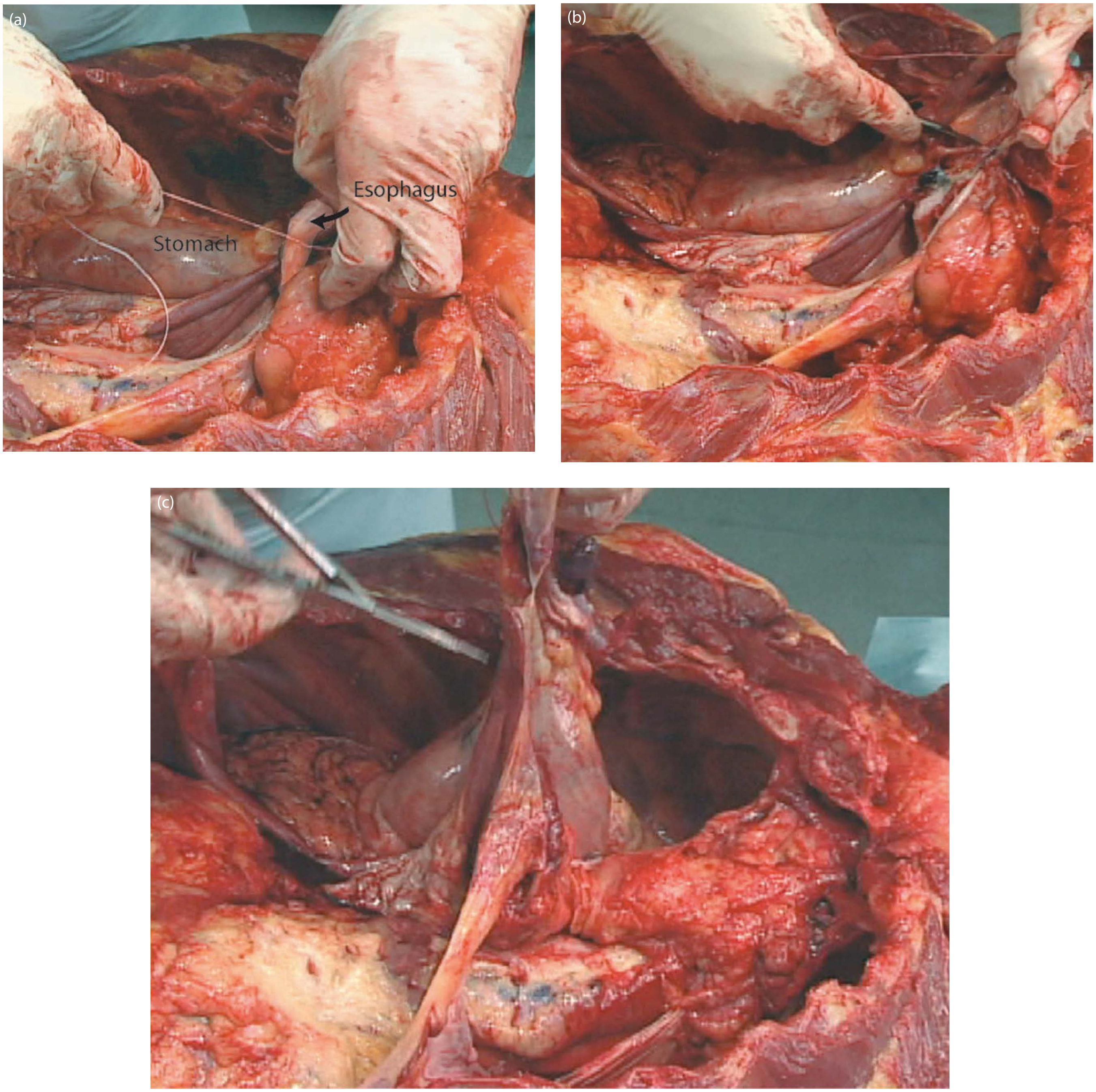


Figure 7.24 (a–c) Removing the esophagus and stomach. The esophagus is tied to prevent loss of gastric contents while the stomach is cut and removed.

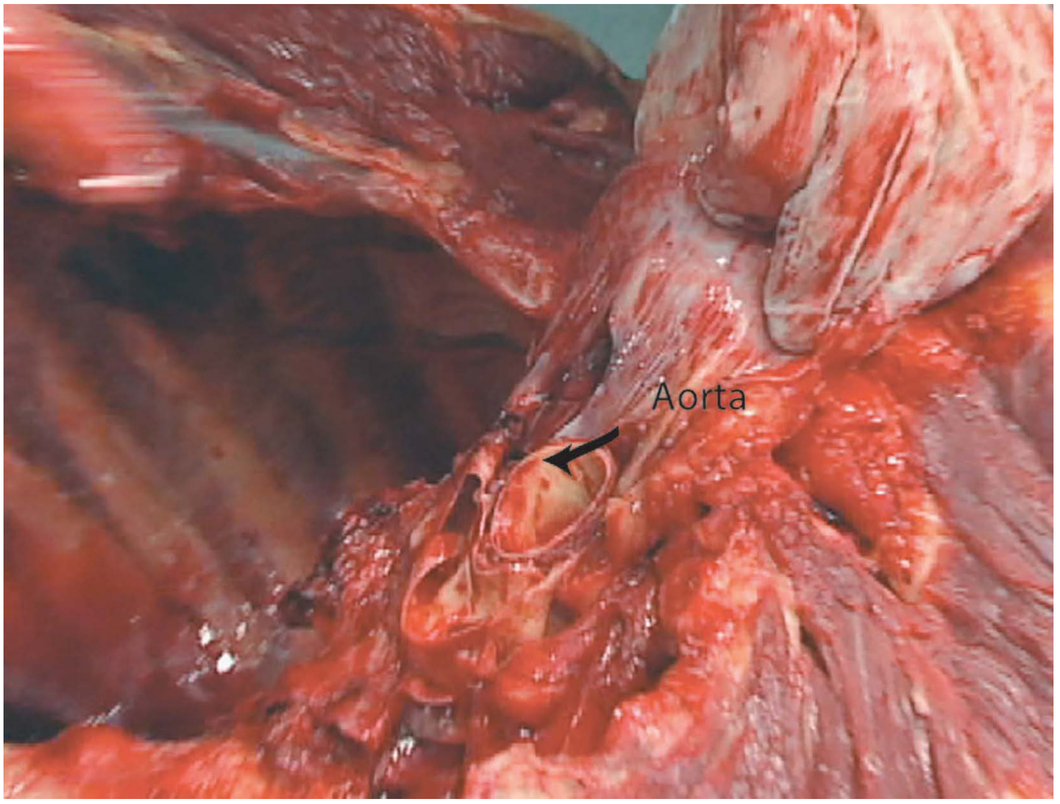


Figure 7.25 Mediastinum examination. The mediastinum is examined for tumors and a thymus. The thymus is usually small after approximately 25 years of age. Lung tumors and other malignancies, such as lymphomas, often spread or "metastasize" to the mediastinum. The aorta is seen in the center.

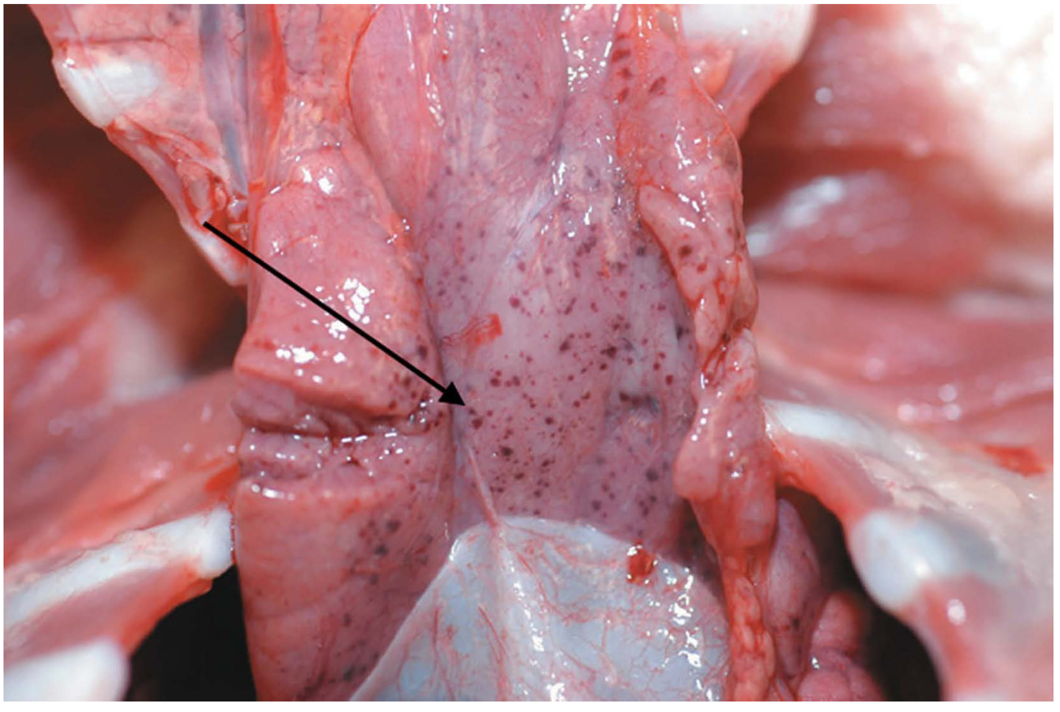


Figure 7.26 Thymus with petechiae. This thymus from a sudden infant death syndrome (SIDS) case shows multiple petechiae. The cause of SIDS is essentially unknown. Many cases are thought to be asphyxial deaths.

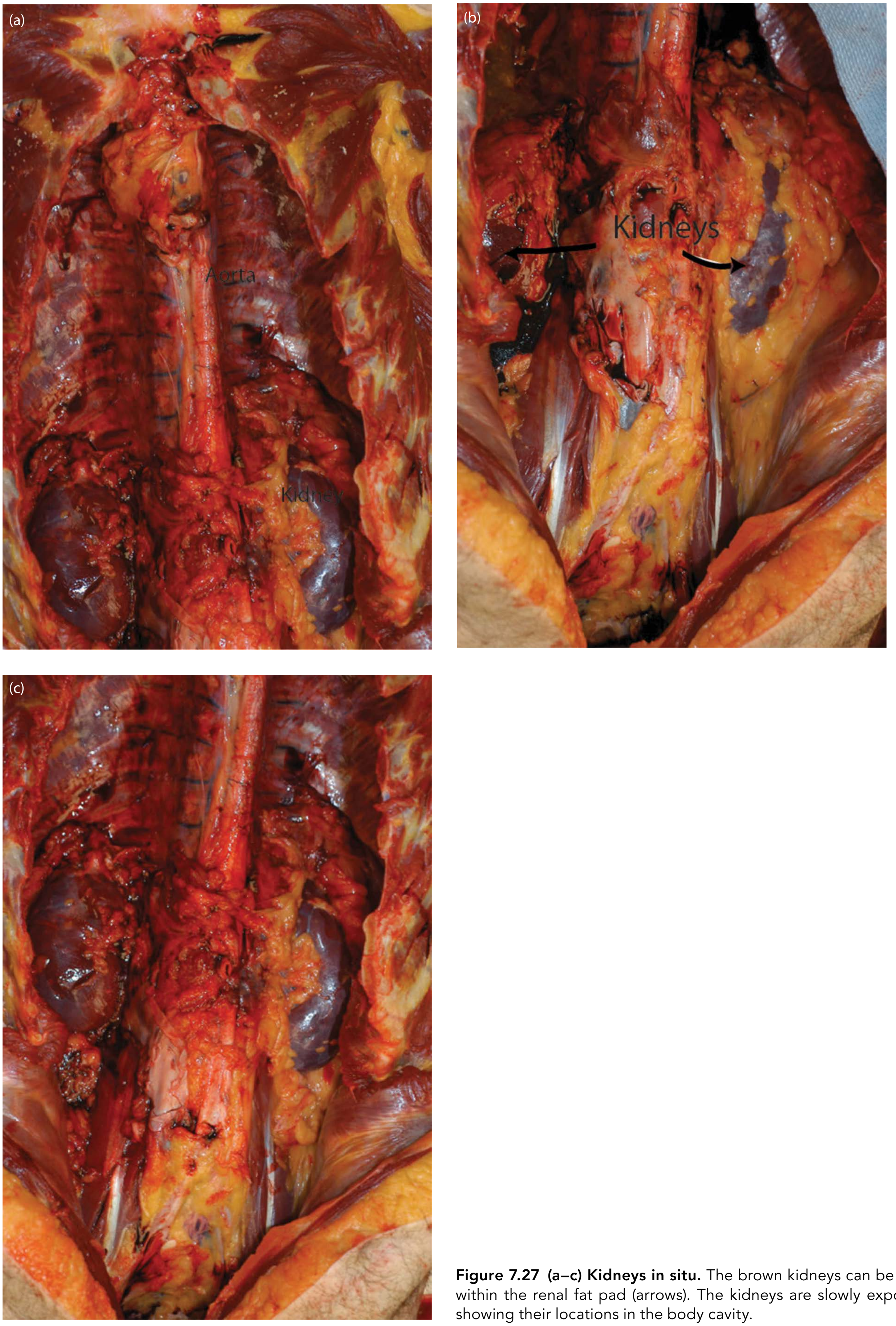


Figure 7.27 (a–c) Kidneys in situ. The brown kidneys can be seen within the renal fat pad (arrows). The kidneys are slowly exposed, showing their locations in the body cavity.

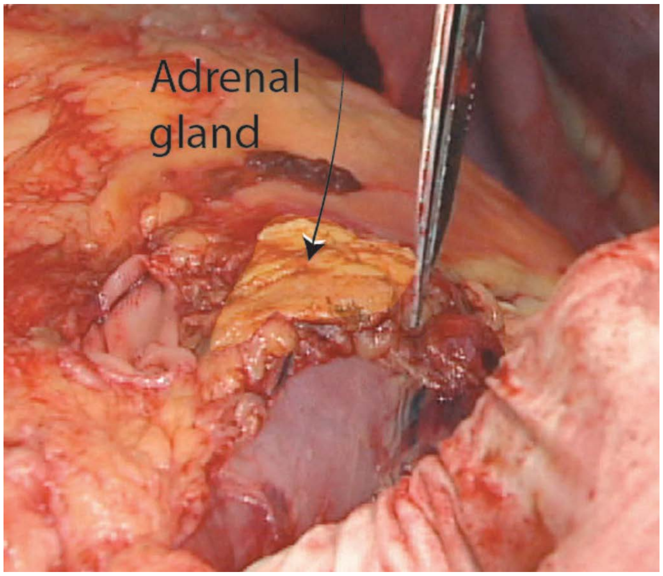


Figure 7.28 Adrenal gland in situ. The adrenal gland is to the left of the scissors and the kidney is hidden below, under the renal fat pad.

Figure 7.29 Adrenal cortical adenoma. The adrenal gland is cut here. The bright yellow cortex contains an adenoma, or nodule. These nodules can be associated with hypertension.

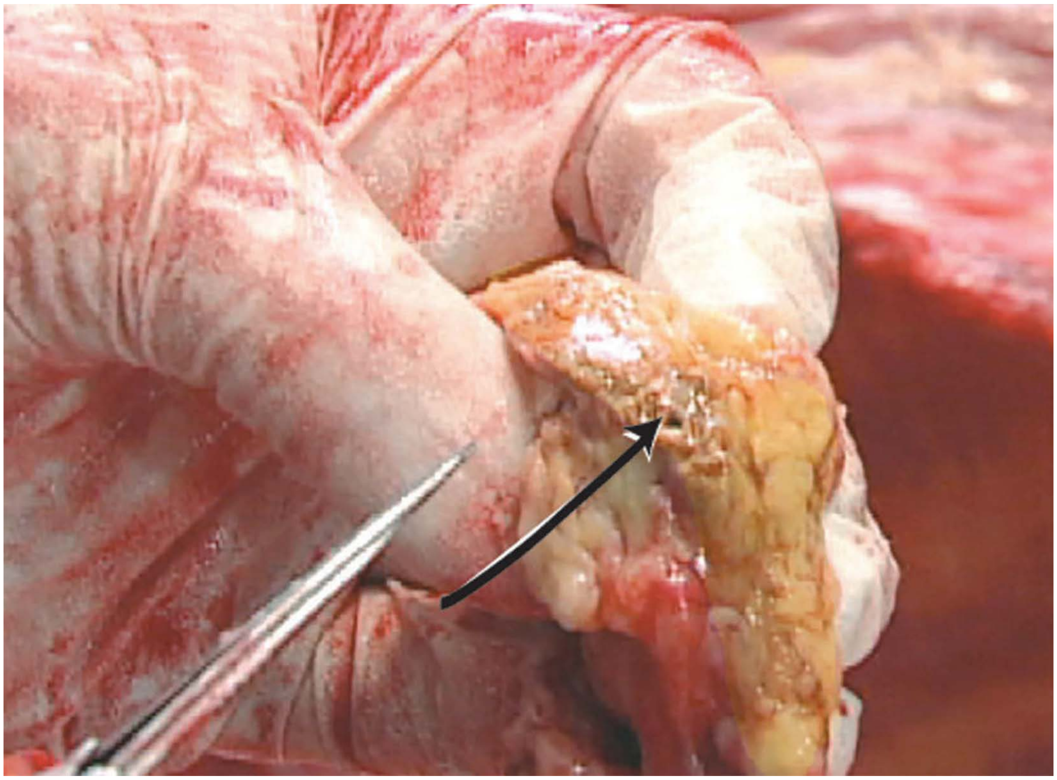
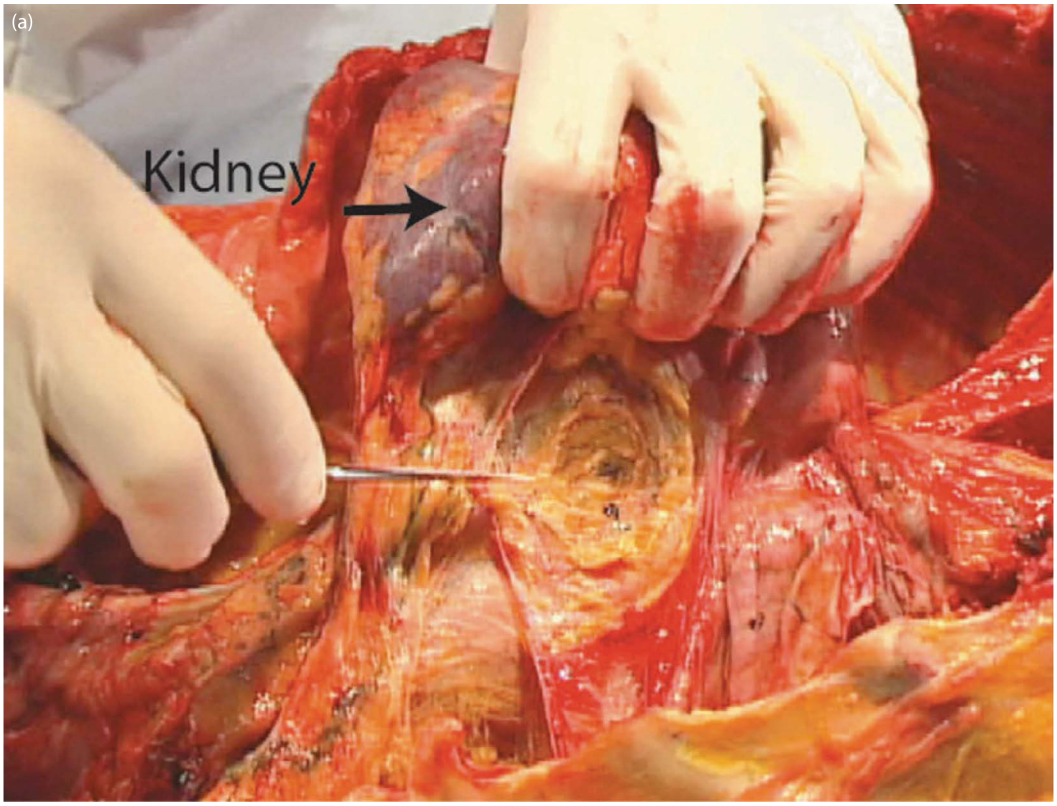


Figure 7.30 Adrenal gland autolysis. The adrenal gland here shows autolysis of the cortex. The adrenal gland is one of the first tissues to autolyze visibly after death.



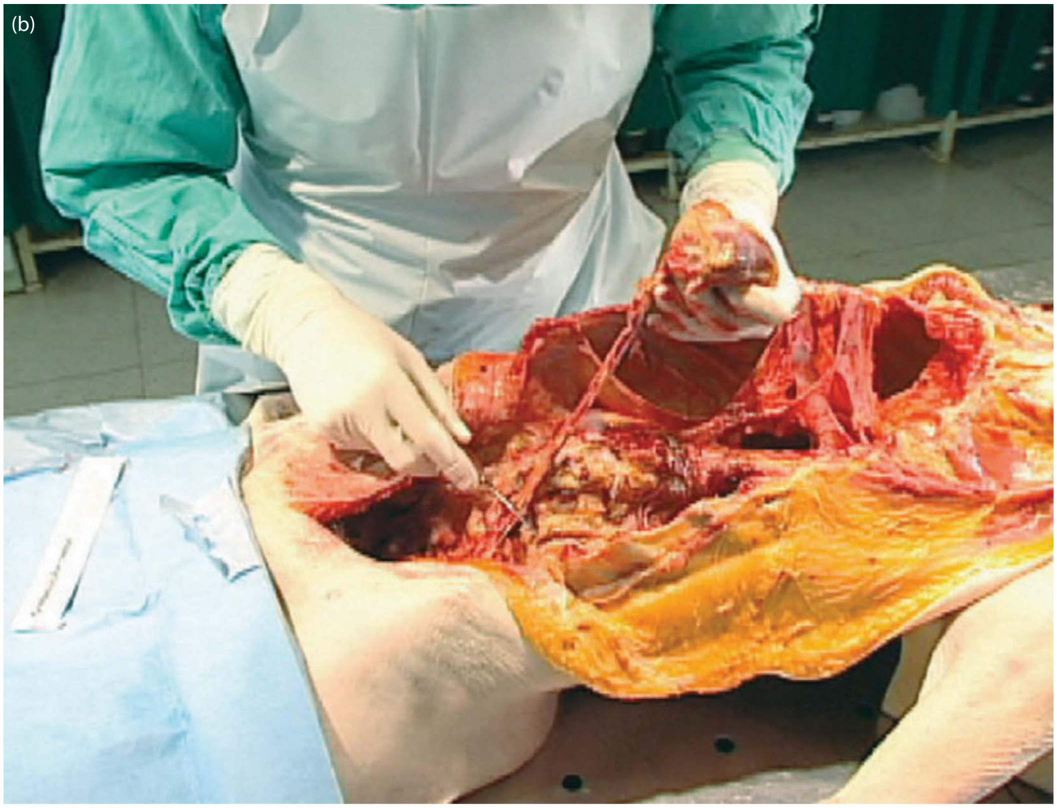


Figure 7.31 (a) Removal of the kidney. The kidney is removed along with the ureter. **(b) Removal of the ureter.** The kidney is in the left hand and the ureter is being cut.

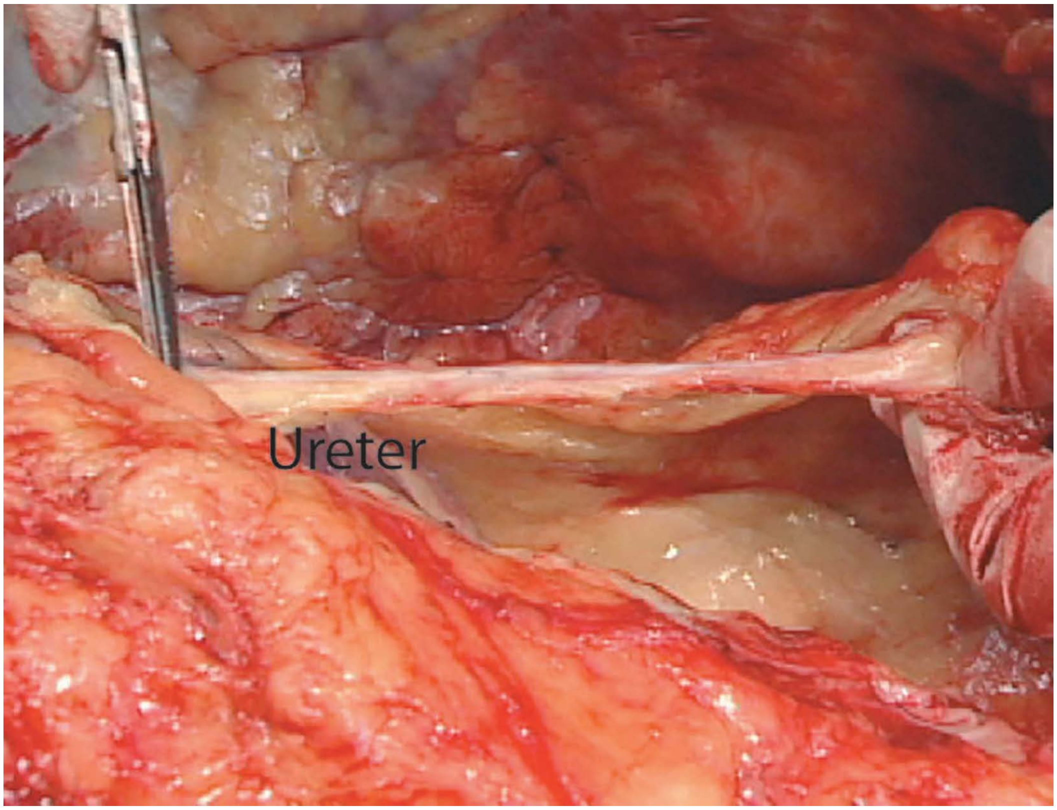


Figure 7.32 Ureter. The ureters are identified as they extend downward to the bladder. The ureters can contain tumors or stones (kidney stones).

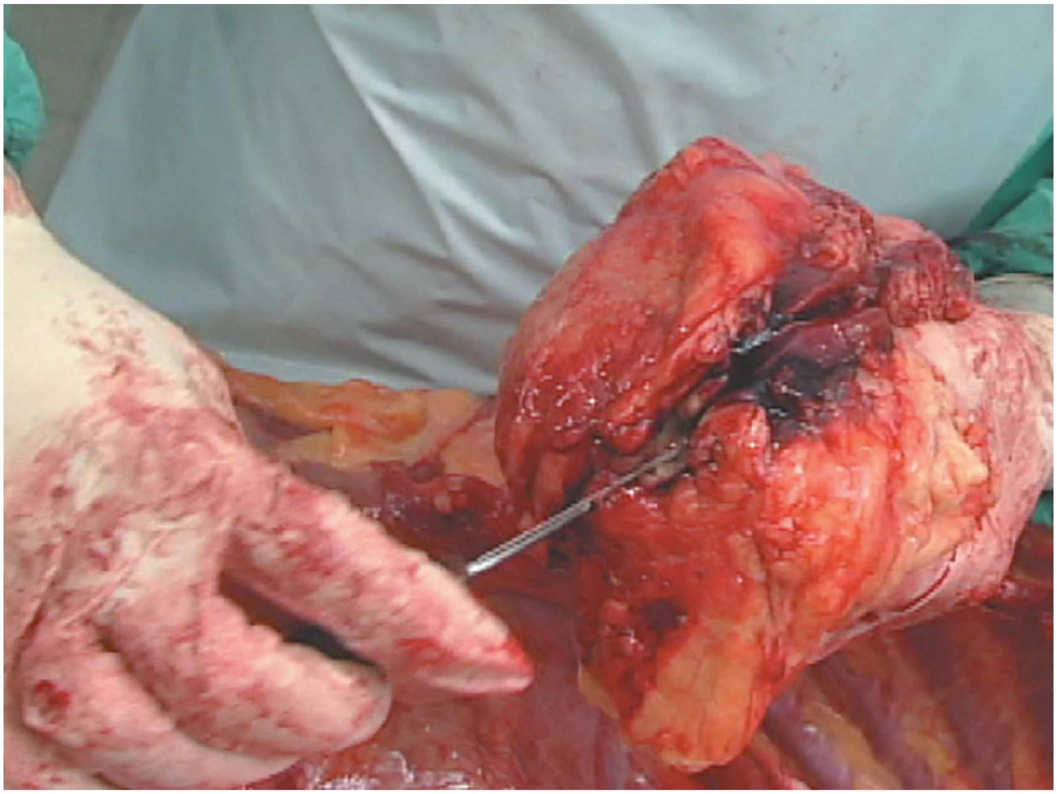


Figure 7.33 Peri-renal fat. The kidney is shown as the renal fat pad that surrounds the kidney is cut.

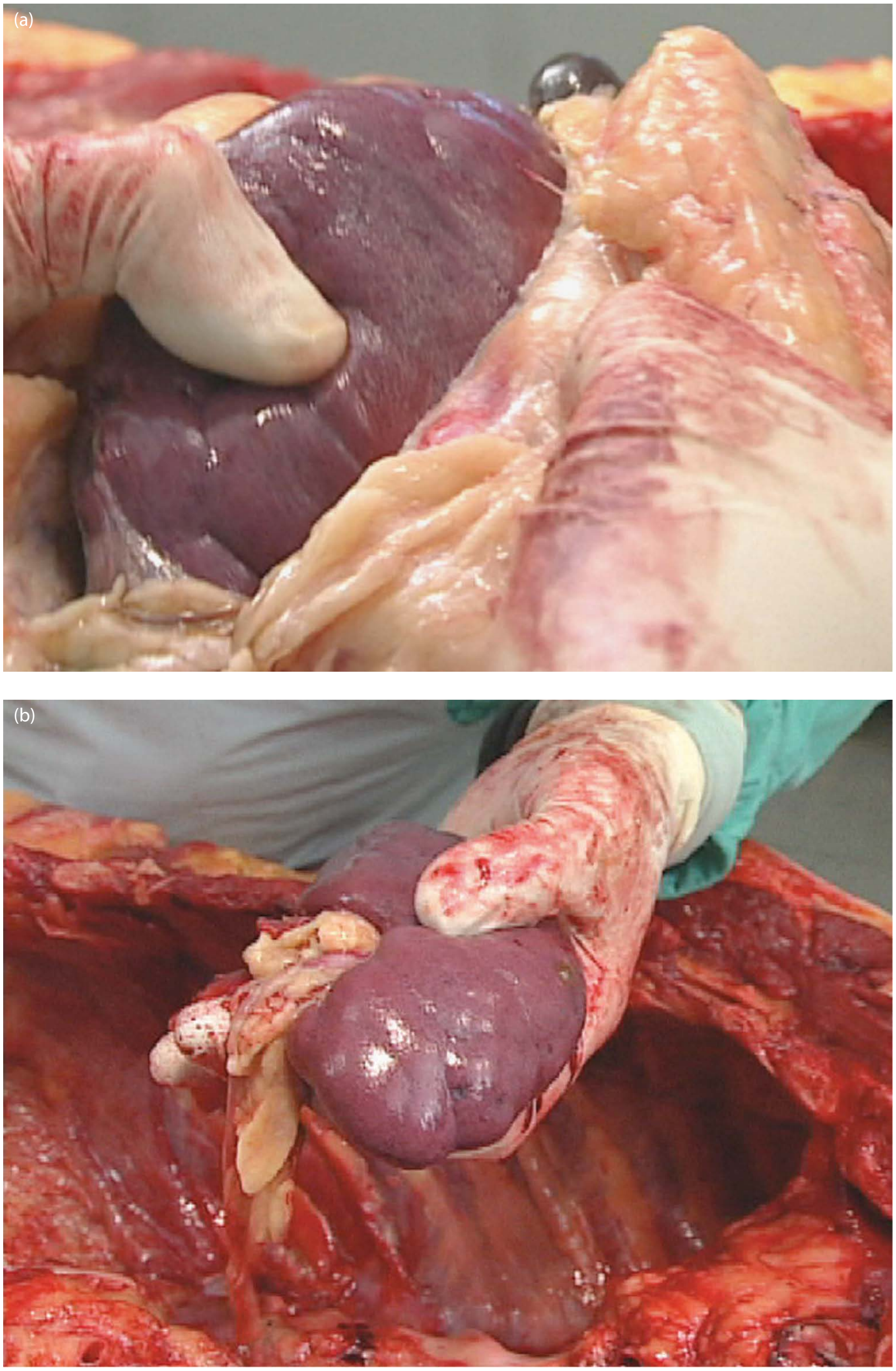


Figure 7.34 (a and b) Removing peri-renal fat. The renal fat pad is stripped away, revealing the kidney beneath.

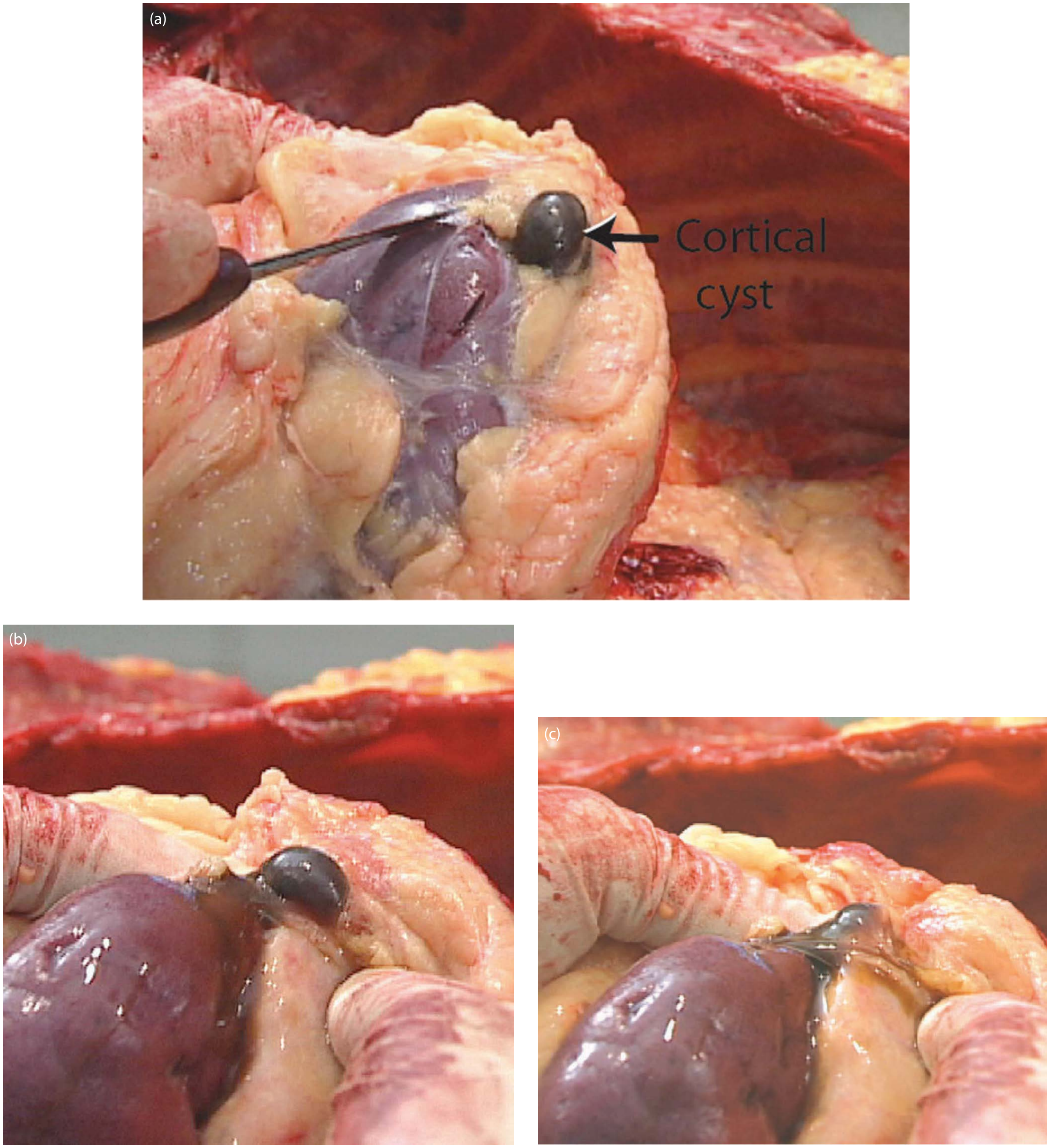


Figure 7.35 (a–c) Renal cortical cyst. After removing the renal fat pad, a cyst is uncovered in the cortex (outer layer) of the kidney. Often, these cysts are very thin and rupture easily upon removal, as happened in this case.

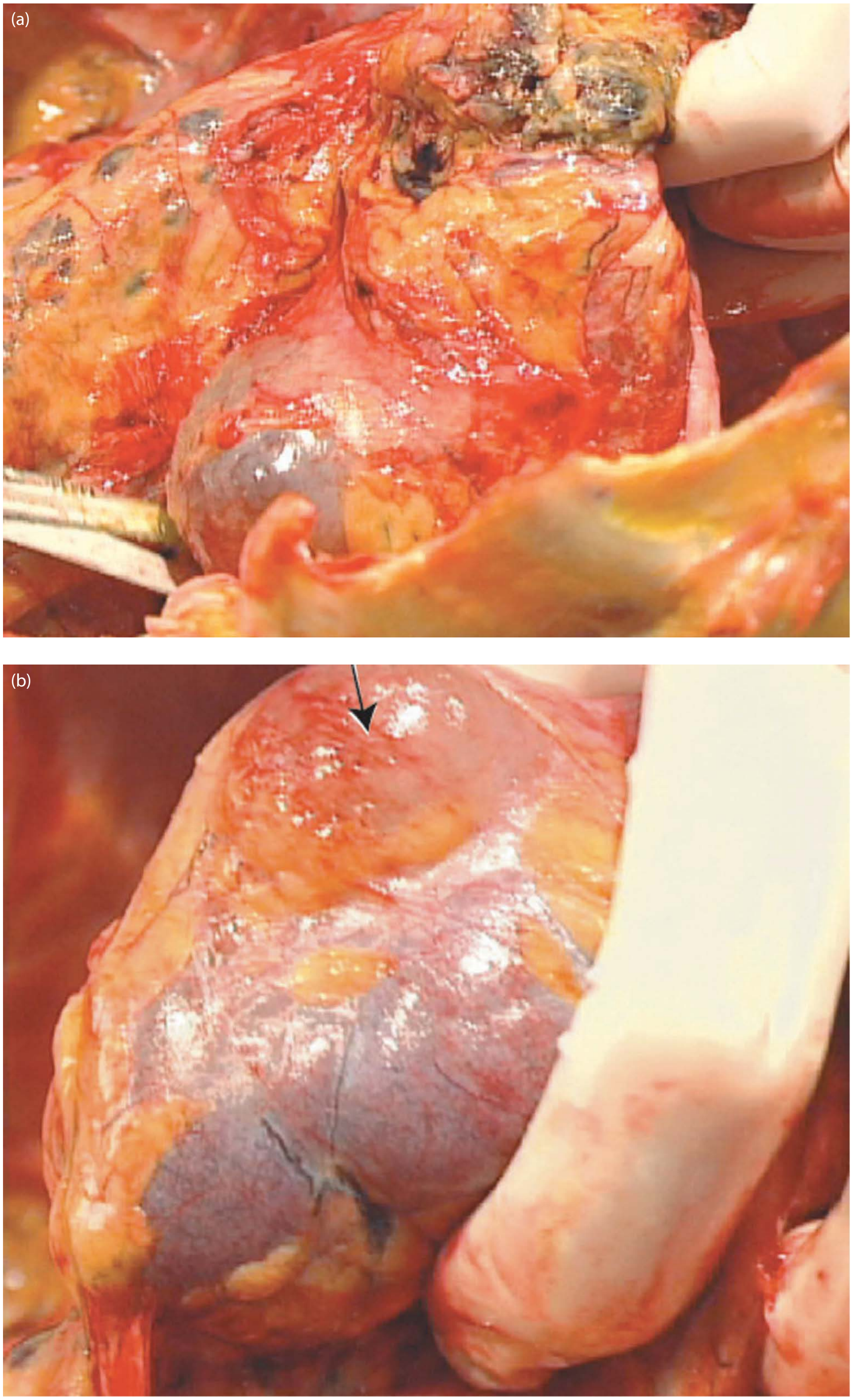


Figure 7.36 (a and b) Renal cortical cyst, large. This cyst (arrow) is very large and thick-walled, staying intact upon removal. This cyst will be opened during the individual organ examination.

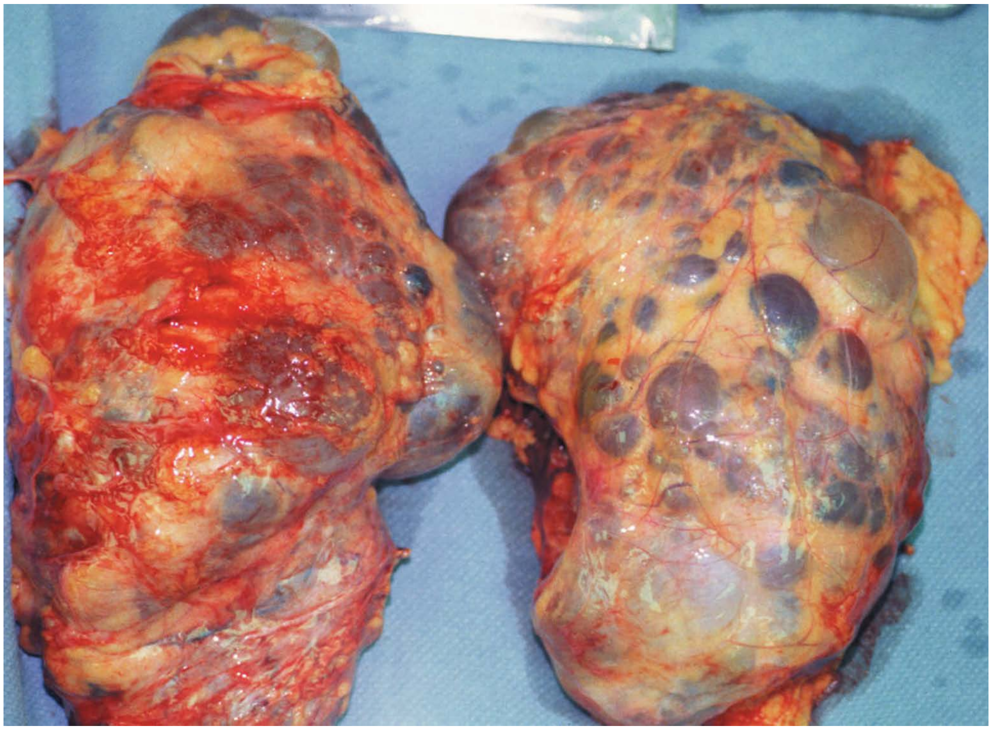


Figure 7.37 Polycystic kidneys. Rarely, the entire kidney is replaced with cysts in a condition called polycystic kidney disease. These patients experience renal failure in their thirties and forties. The kidneys depicted are over twice the usual size and weight.

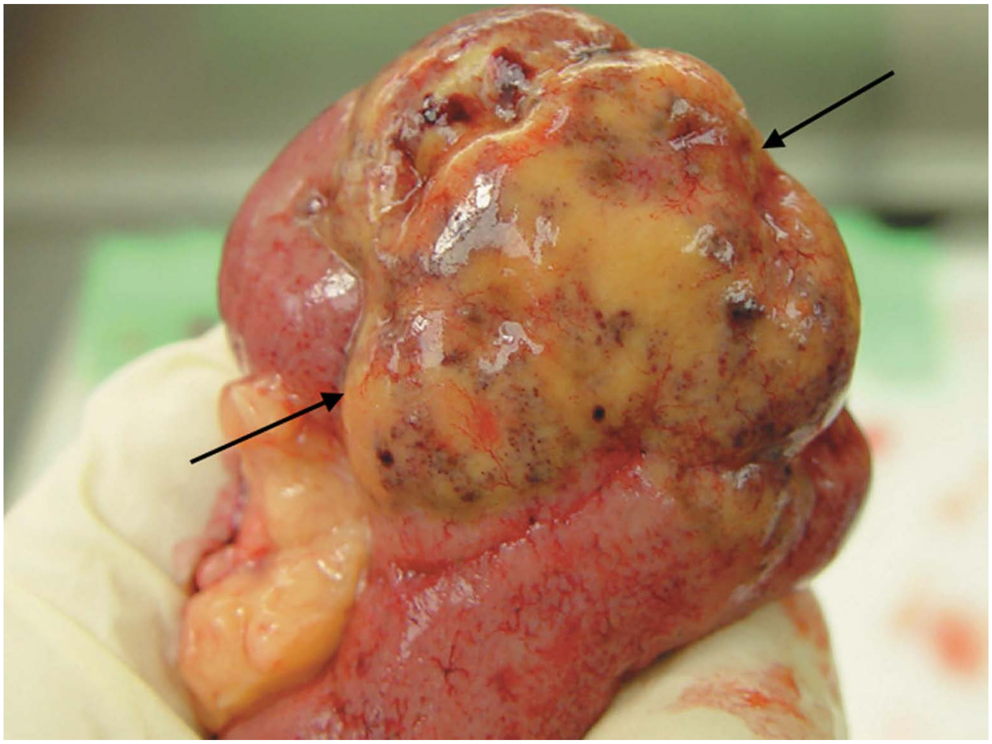


Figure 7.38 Renal cell carcinoma. Large tumors can be encountered upon removing the kidneys. This yellowish, rounded tumor is a renal cell carcinoma, a common malignant tumor of the kidney.

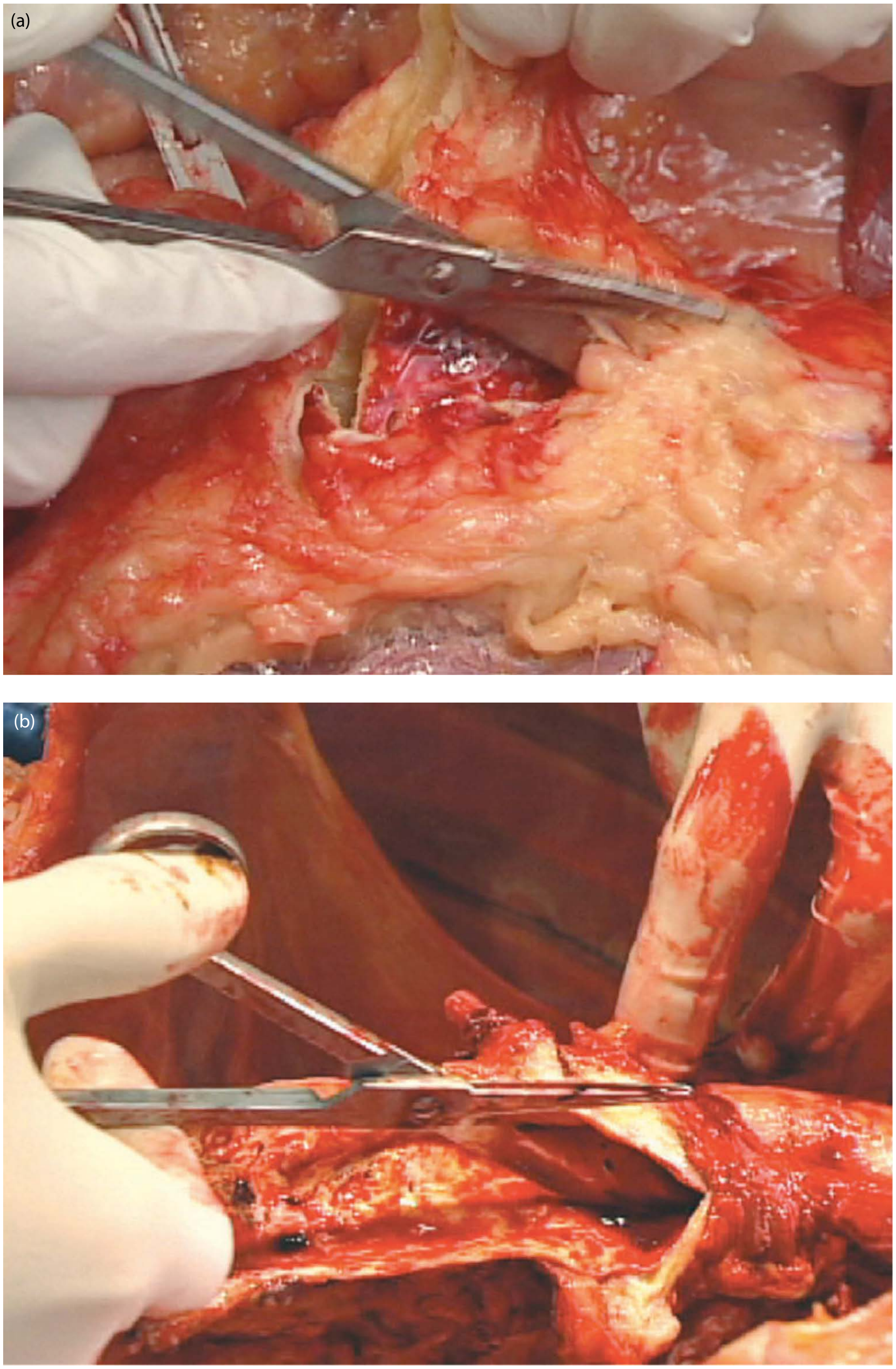


Figure 7.39 Opening the aorta. (a–c) The aorta is opened from the iliac bifurcation up to the ascending aorta. (*Continued*)

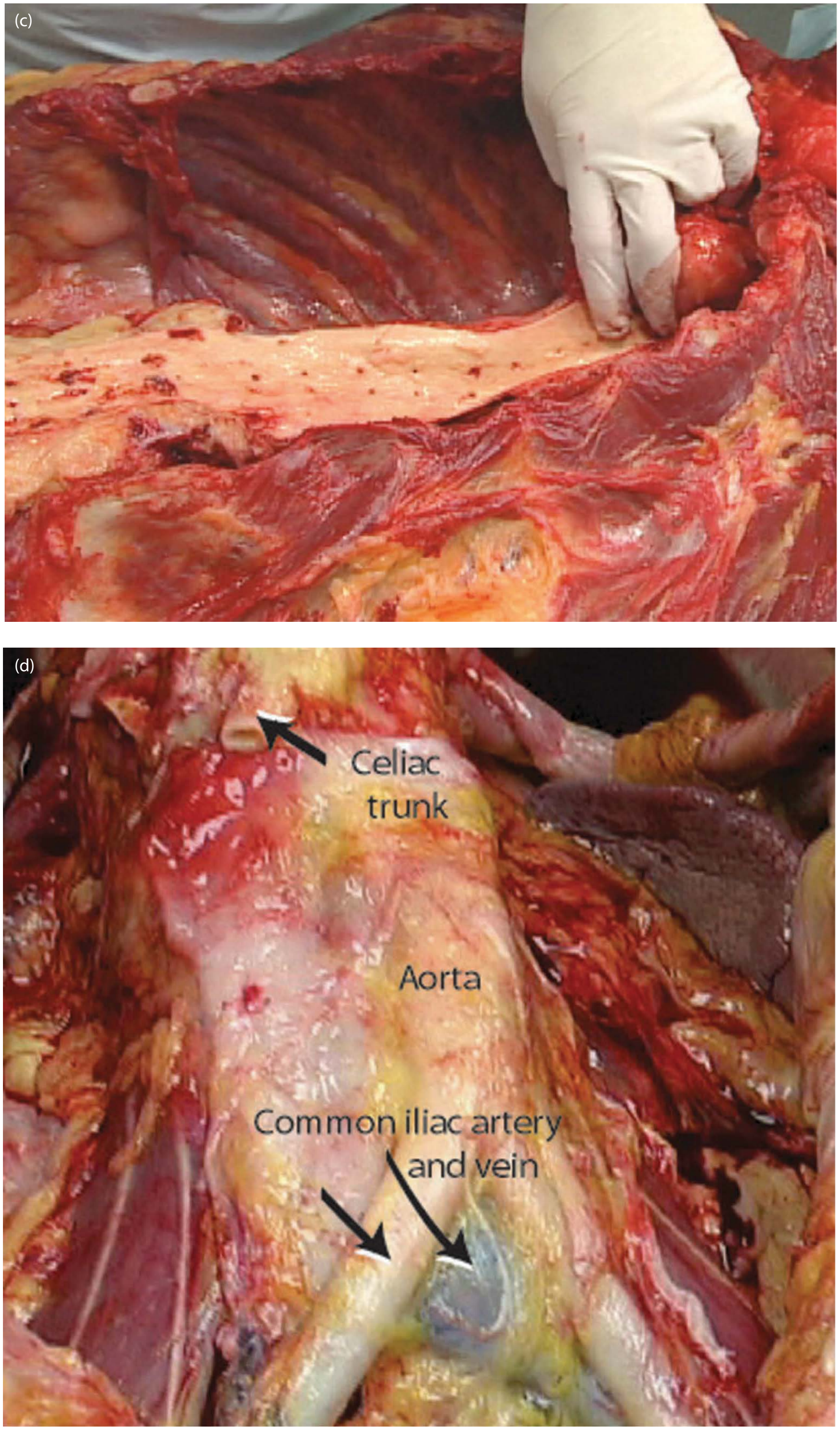


Figure 7.39 (*Continued*) Opening the aorta. (d) The abdominal aortic anatomy is displayed.

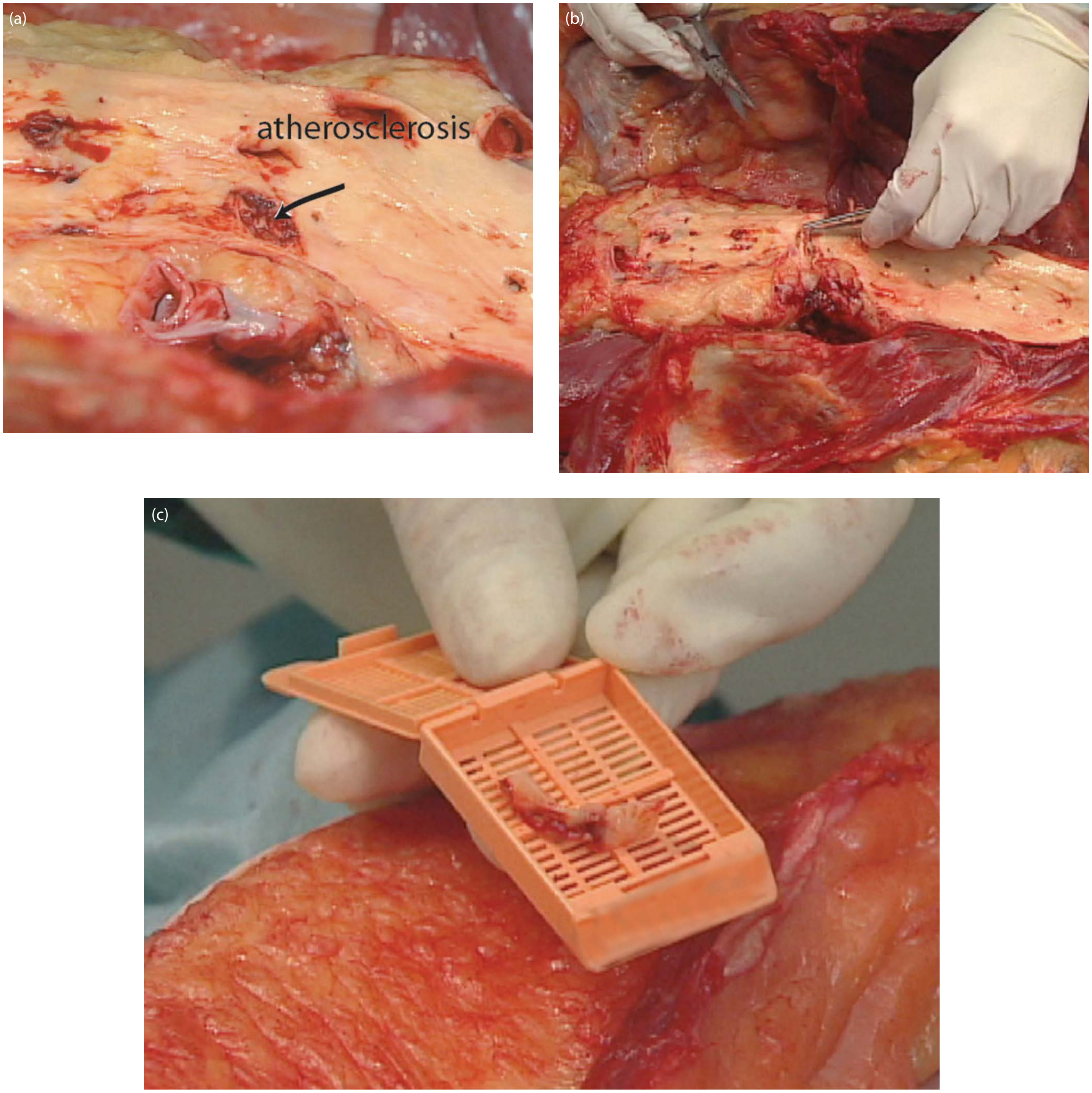


Figure 7.40 Aortic atherosclerosis. (a and b) An atherosclerotic ulcer is seen in the middle of the image. **(c)** A section of this plaque is submitted in a histology cassette so that it can be processed to a glass slide and reviewed under the microscope.

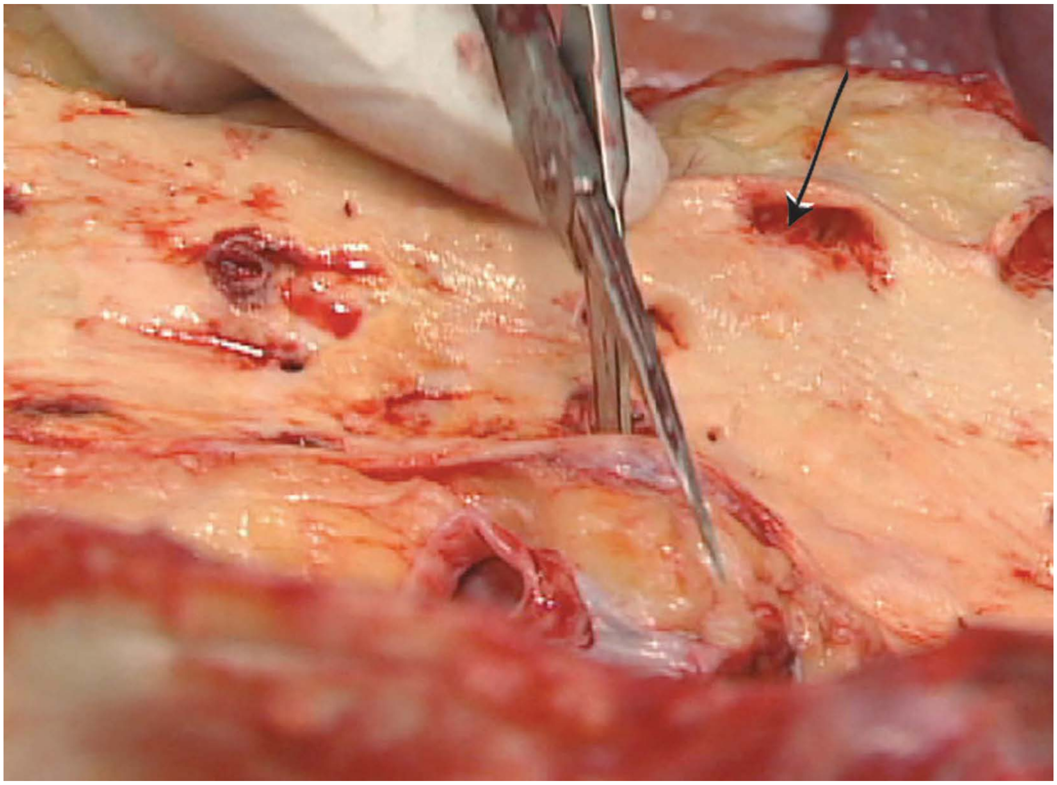


Figure 7.41 Renal artery. The scissors is in the renal artery. This artery is opened to check for stenosis of the artery, one of the clinical causes of hypertension. The other renal artery is indicated by the arrow.

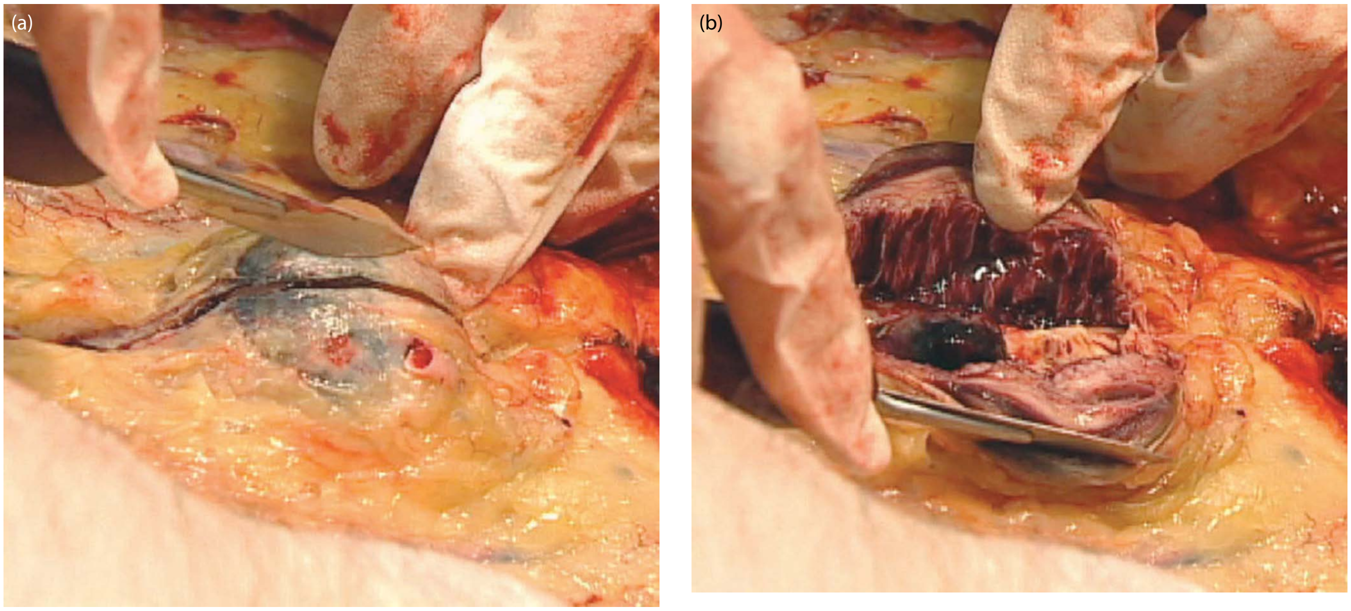


Figure 7.42 Abdominal aortic aneurysm. (a) The scalpel points to a bluish–purple knob in the region of the abdominal aorta, partially obscured by retroperitoneal fat. **(b)** The aneurysm is incised to reveal the thick aneurysmal wall.

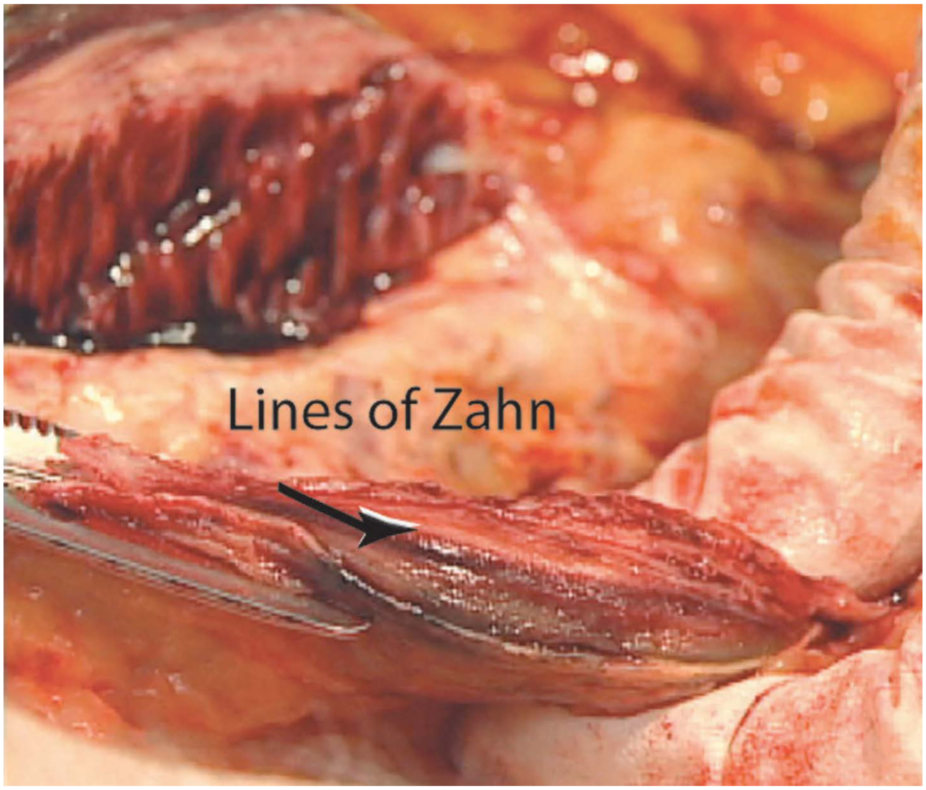
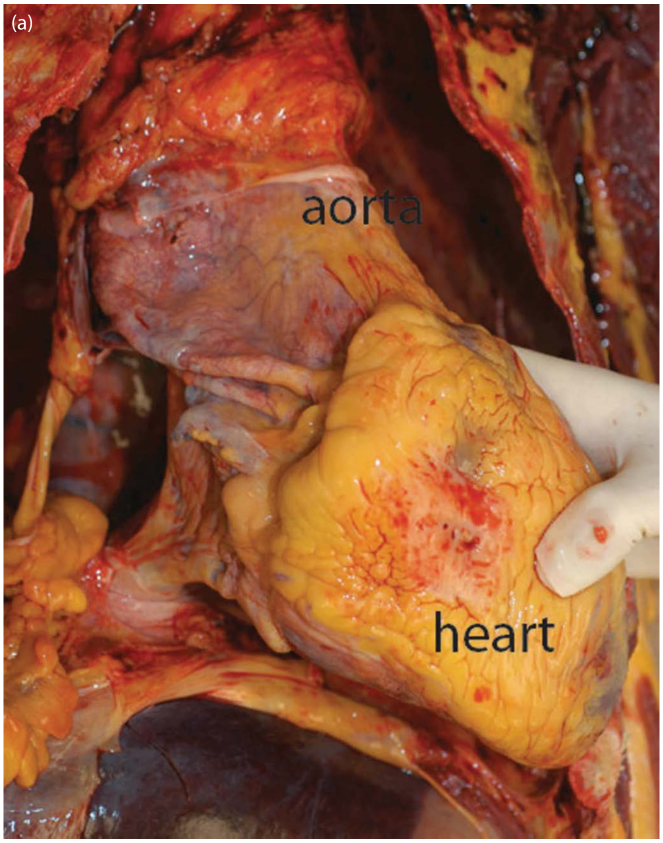


Figure 7.43 Aortic aneurysm wall showing lines of Zahn. An aneurysm is an outpouching of a blood vessel wall, in this case caused by atherosclerosis. The aneurysm is exposed, and the wall is cut open to reveal a thick, layered wall. The alternating light and dark lines demark layers of white blood cells (light) and red blood cells, fibrin, and platelets (dark).



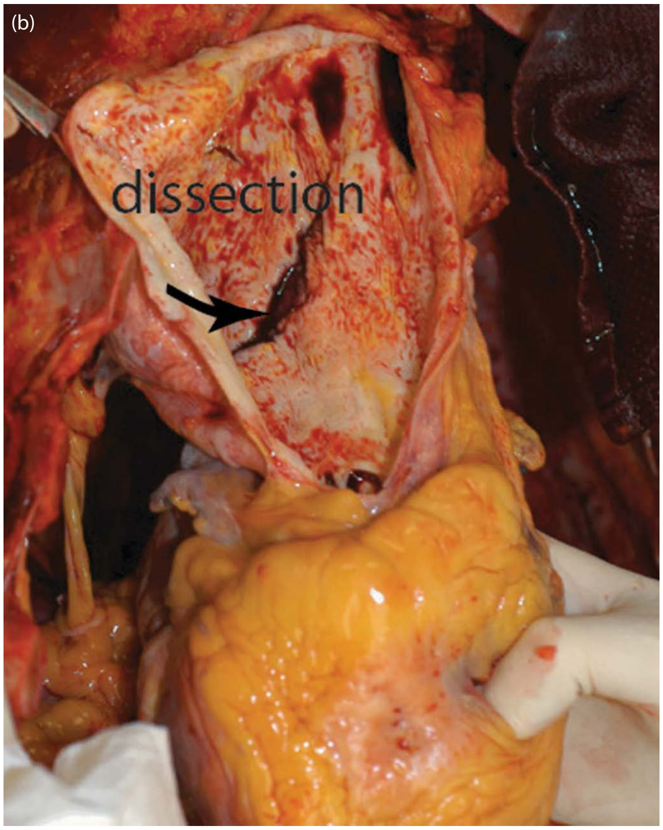


Figure 7.44 (a and b) Ascending aortic aneurysm. Another type of aneurysm is seen near the heart, involving the aortic root. The broad structure shown by the arrow is the aorta. This individual was suspected of having Marfan's syndrome, a connective tissue disease associated with the weakening of blood vessel walls. **(b)** Aortic dissection. This figure shows the opened aorta, which contains a large tear. The thin aneurysm can tear spontaneously, allowing blood to dissect outside the aorta, resulting in an aortic dissection.

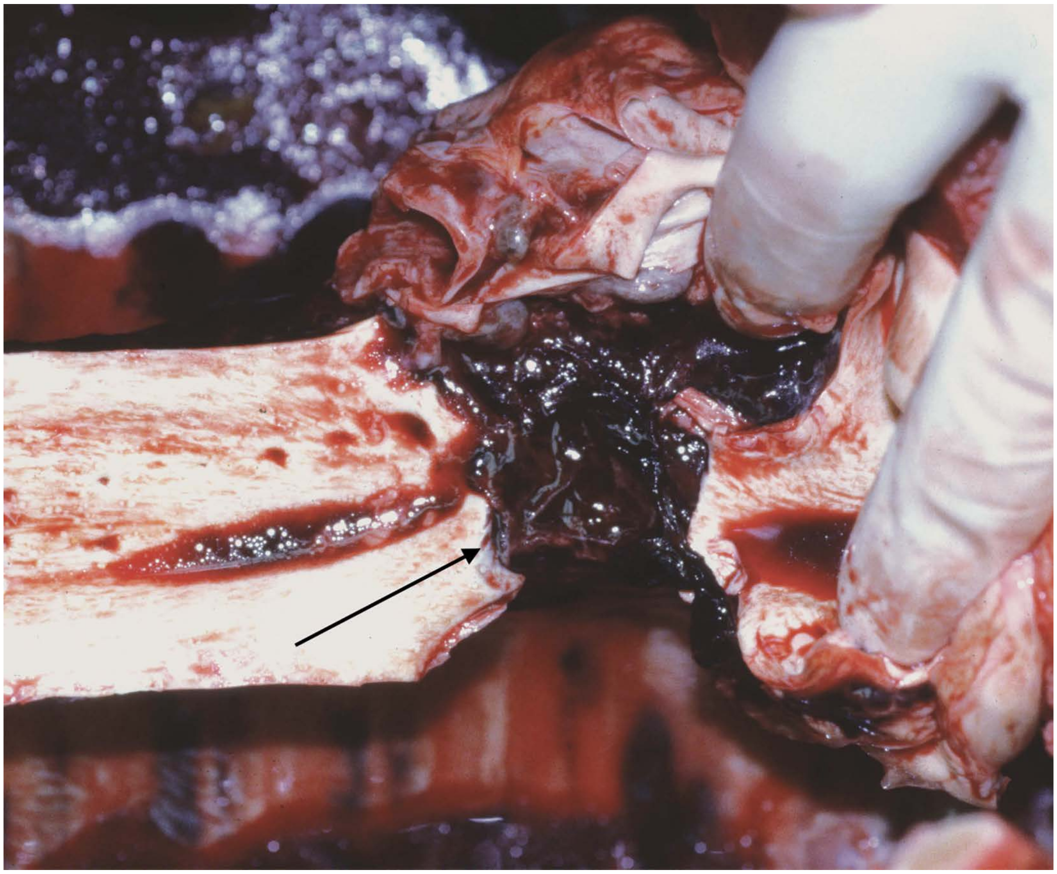


Figure 7.45 Laceration of the aorta. In a severe trauma, such as one caused by a motor vehicle crash, the aorta can be lacerated or completely transected as seen here.

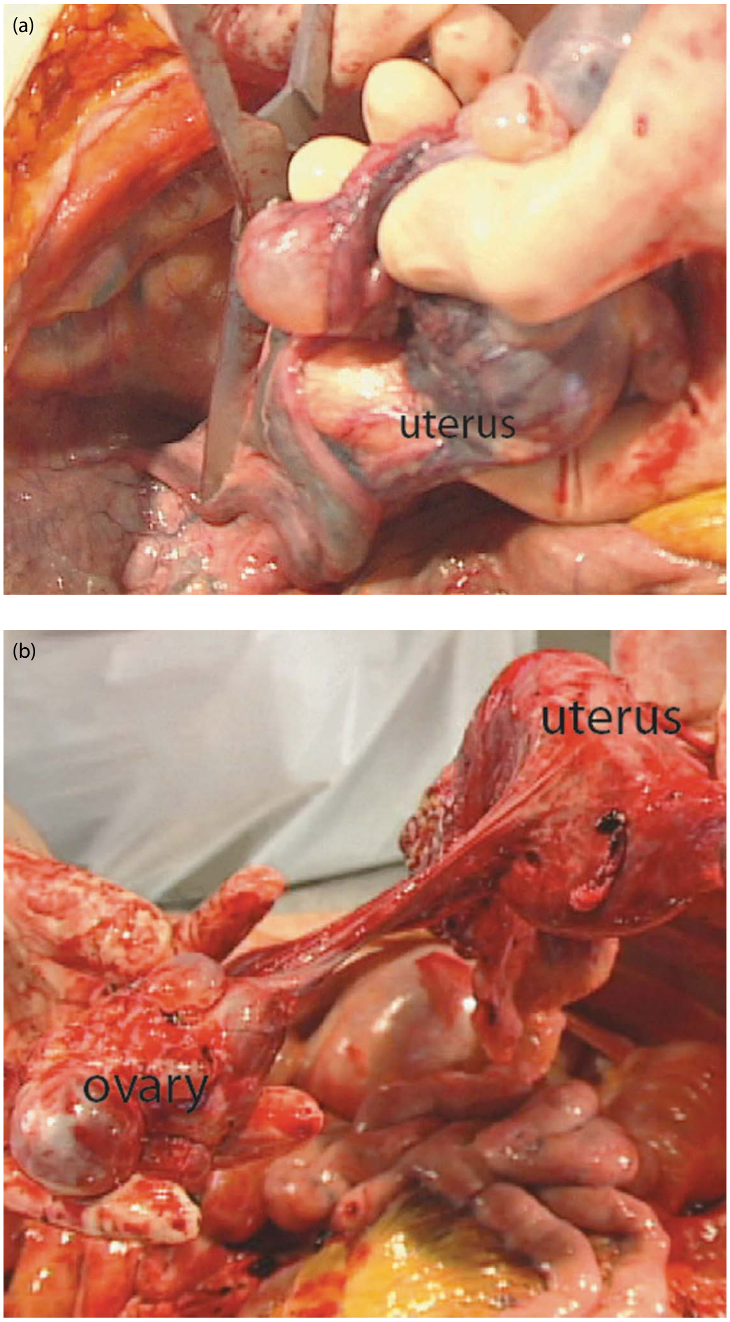


Figure 7.46 Removal of the uterus and ovaries. (a) The uterus is excised from the lower pelvis and is removed separately from or with the bladder. The uterus is displayed with two attached ovarian cysts. **(b)** A large cyst can be seen on the left side of the figure (also see Figure 6.35a and 6.35b). Upon removal of these and other organs, the natural appearance of the tissues is often partially obscured by blood. This blood can easily be washed off, as is done when the tissues are examined in the individual organ examination portion of the autopsy.

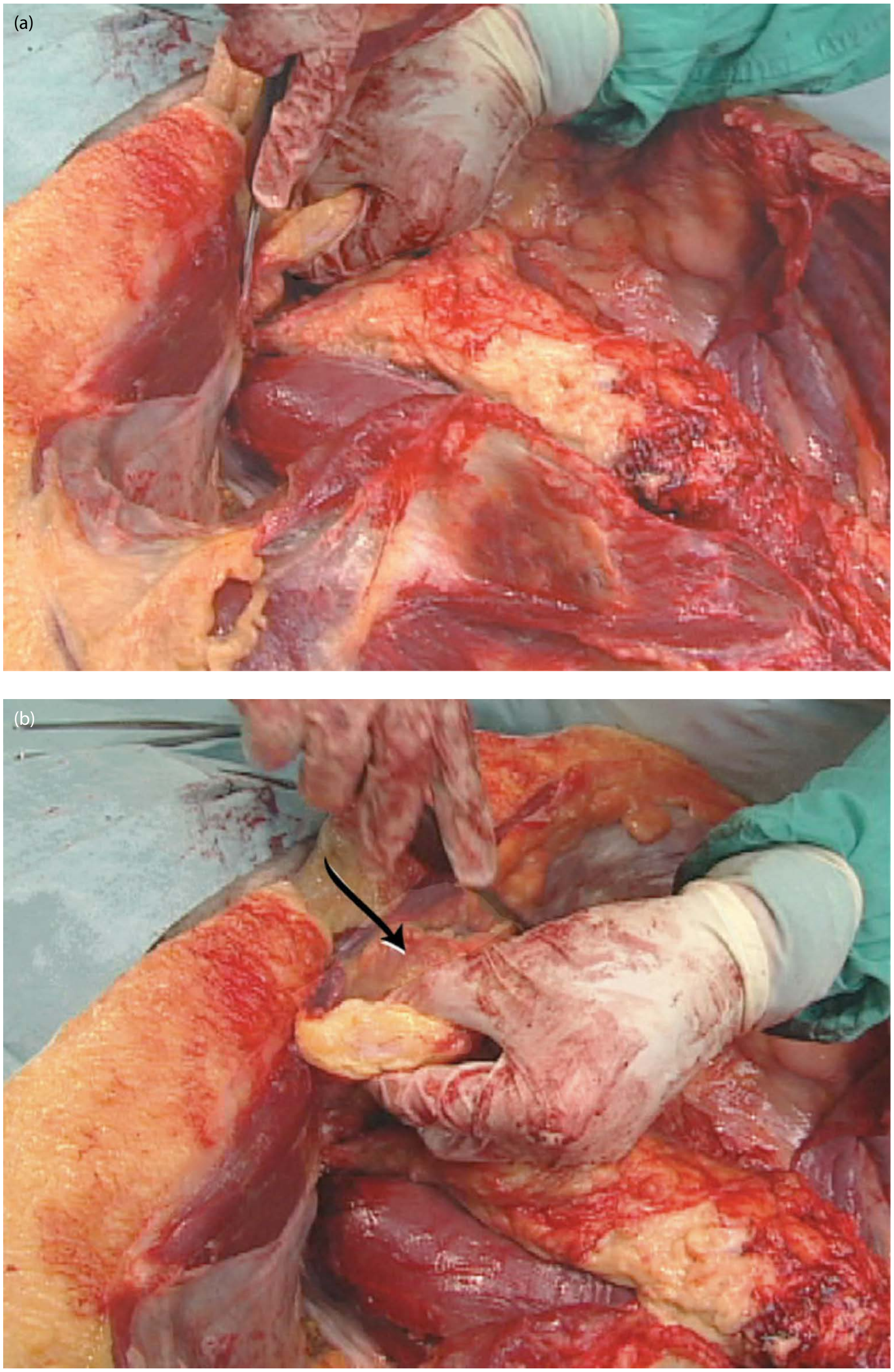


Figure 7.47 (a–d) Removal of the bladder. The pathologist dissects the bladder from the lower pelvis in the male, being careful to include the prostate gland. The bladder is held in the left hand (arrows). The pathologist must be careful not to empty urine from the bladder. If only a small amount of urine is present at the initial aspiration for toxicology, a small amount of additional urine can often be obtained by carefully opening the bladder. (*Continued*)

Figure 7.47 (*Continued*) (a–d) Removal of the bladder. The pathologist dissects the bladder from the lower pelvis in the male, being careful to include the prostate gland. The bladder is held in the left hand (arrows). The pathologist must be careful not to empty urine from the bladder. If only a small amount of urine is present at the initial aspiration for toxicology, a small amount of additional urine can often be obtained by carefully opening the bladder.

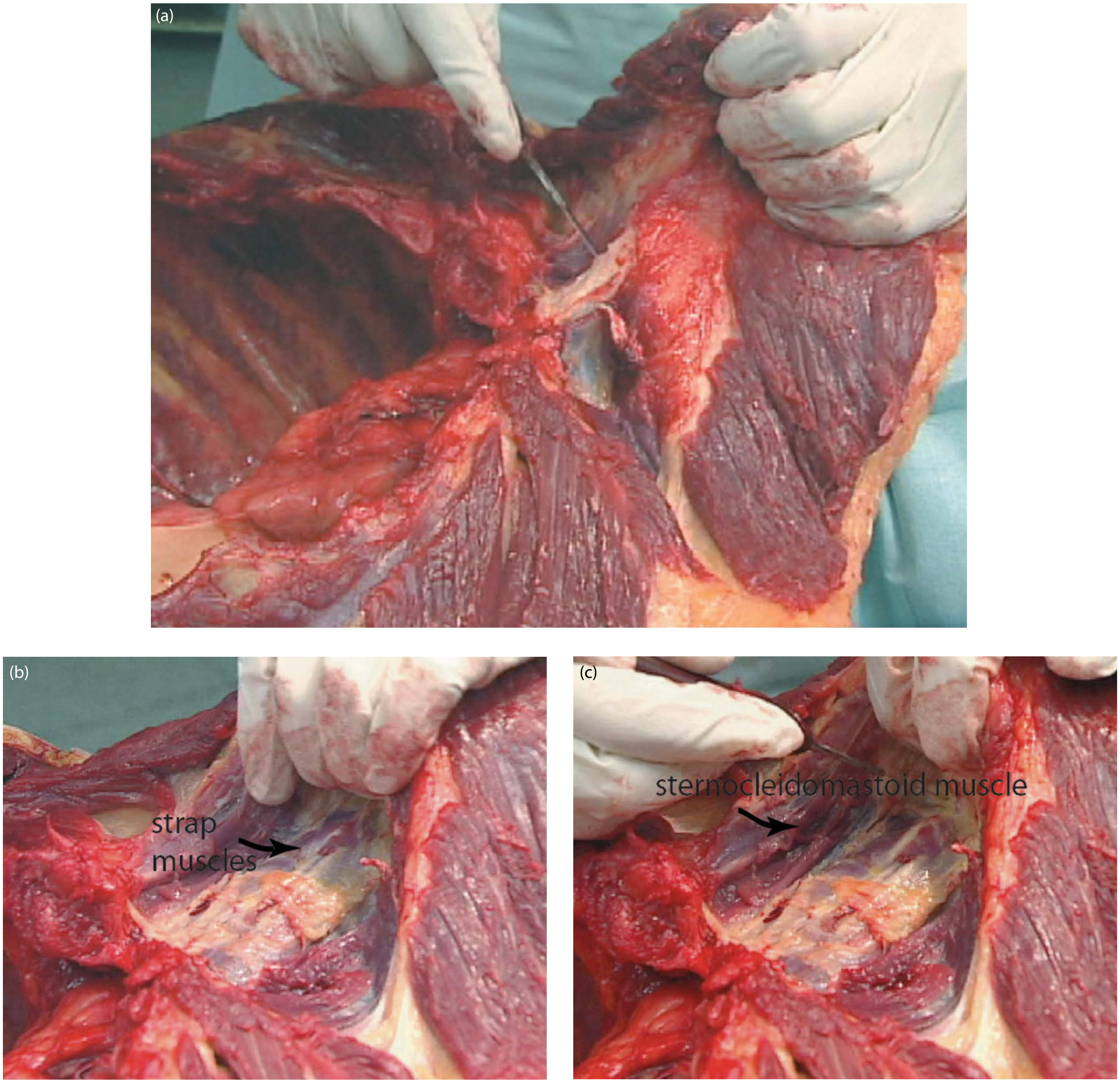


Figure 7.48 (a–c) Neck dissection, exposing muscles. The neck is dissected after the viscera have been removed. While applying traction to the upper chest skin and soft tissue flap, the “strap” muscle group (midline) and sternocleidomastoid (lateral) are revealed during careful dissection. The main focus of the dissection is to look for hemorrhage. If hemorrhage is discovered at any step, the dissection is photographed as it progresses. Suspected strangulation cases are imparted an even more detailed dissection than depicted here.

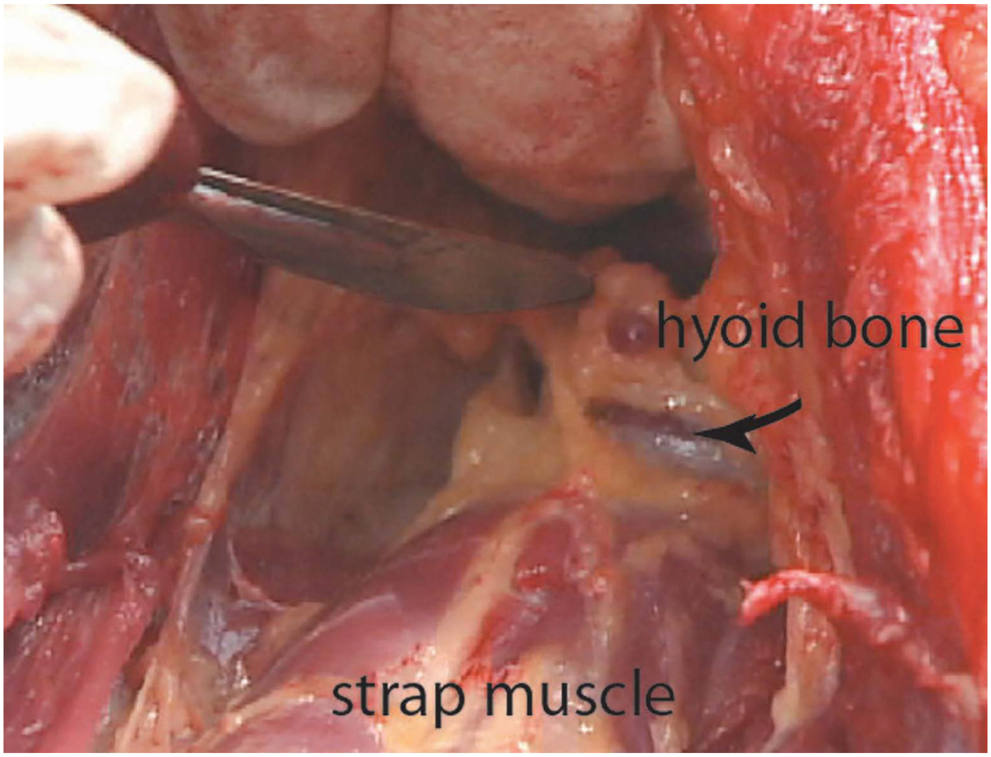


Figure 7.49 Neck dissection, cutting above the hyoid bone. The dissection is carried up high into the neck and a cut is made in the muscle above the hyoid bone, a horseshoe-shaped bone that can be broken during strangulation. The tongue is removed with the other neck organs in certain cases, such as strangulation, or when the tongue needs to be examined directly. Some pathologists remove the tongue in all autopsies. The forensic autopsy is incomplete without at least the complete removal of the hyoid bone with the neck organs.

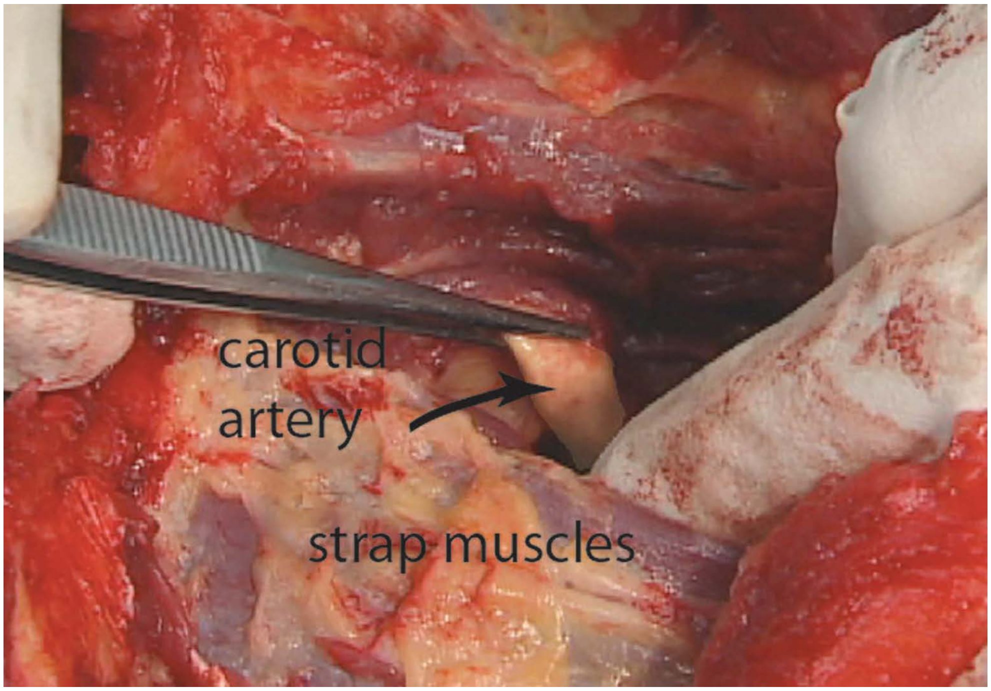


Figure 7.50 Neck dissection, exposing the carotid artery. The lateral soft tissue of the neck is cut away, revealing the carotid artery.

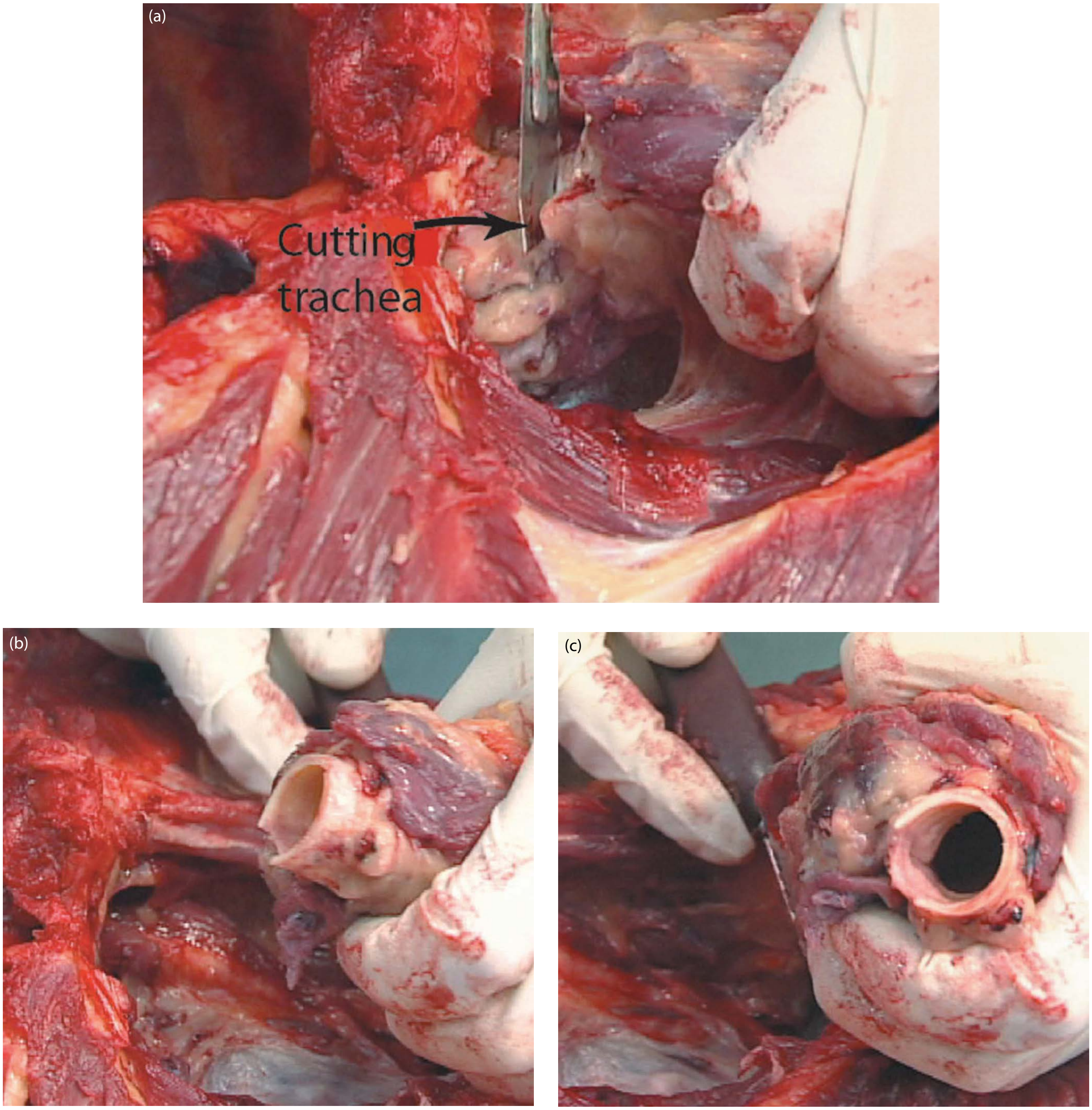


Figure 7.51 (a–c) Neck dissection, cutting the trachea. The trachea and esophagus are cut while traction is placed with the left hand. The pathologist is careful to cut away the tissue without cutting the carotid arteries, since the embalmer uses the carotid arteries to embalm the head. Cutting the carotids makes them difficult for the embalmer to find.

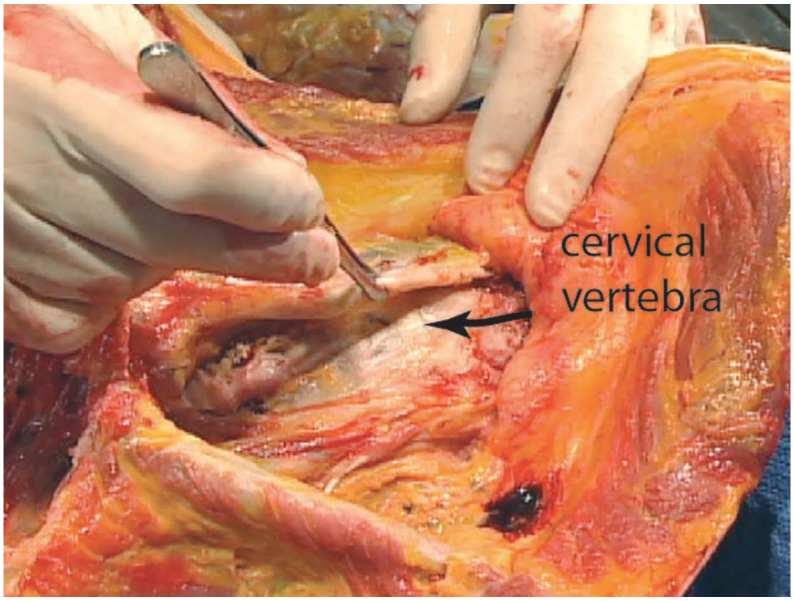


Figure 7.52 Carotid artery relationships. The carotid artery is shown by the forceps. The neck organs have been removed. The cervical vertebrae are just below the artery. Significant hemorrhage or fracture of the cervical vertebrae can be seen at this stage of the dissection (see Figure 7.53).

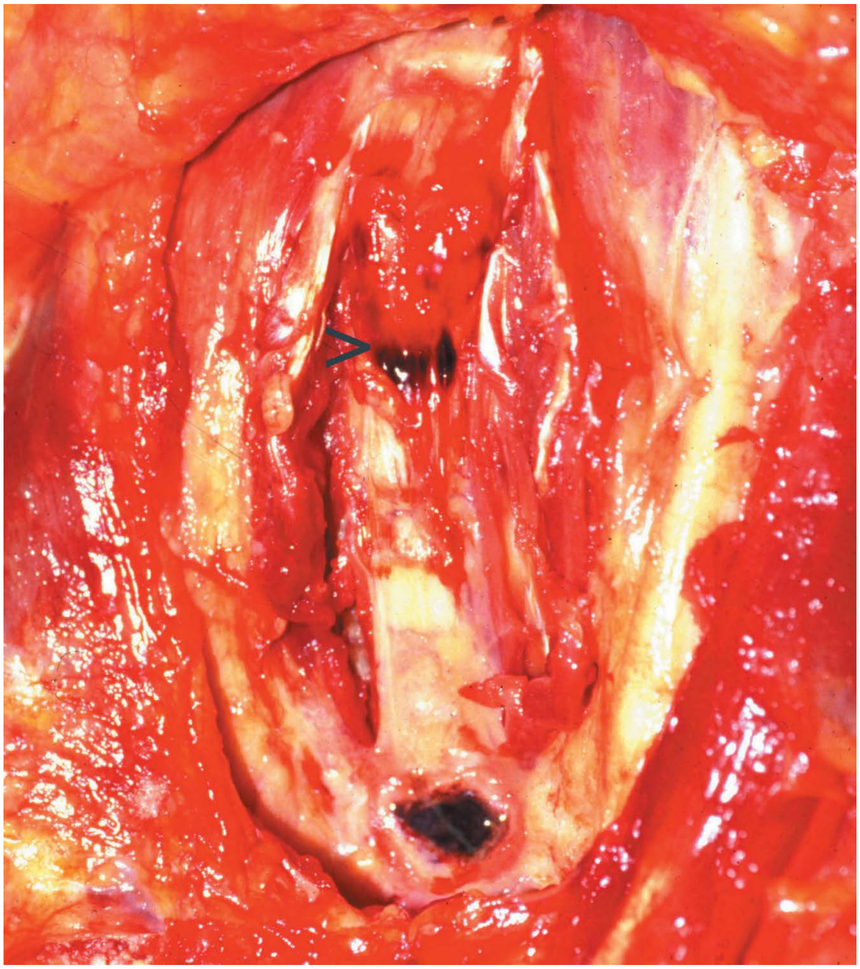
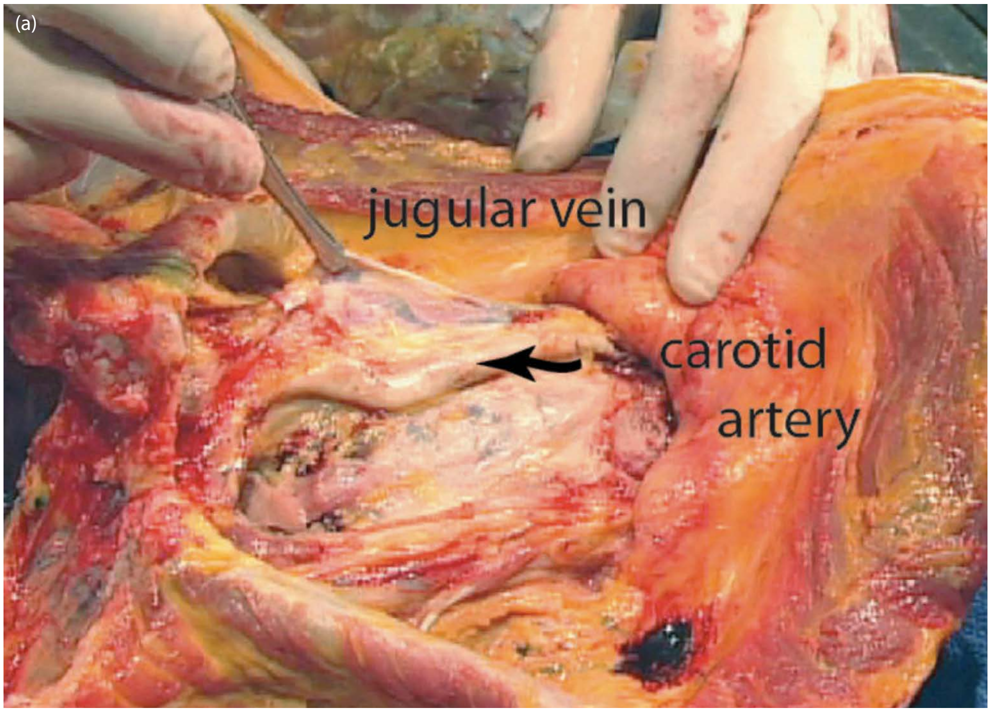


Figure 7.53 Cervical vertebra fracture. Removal of the neck shows hemorrhage due to the fracture of a vertebral body in the neck (arrow). This victim suffered this and other blunt force injuries while being murdered. Fracture of the cervical vertebrae often results in swelling and hemorrhage of the spinal cord. The higher the injury is on the spinal cord, the more severe the effect on the victim. Damage of the spinal cord at levels 3, 4, and 5 can cause paralysis of the diaphragm, for example, resulting in respiratory failure. An x-ray can be helpful if obvious fracture or hemorrhage is not seen during examination.



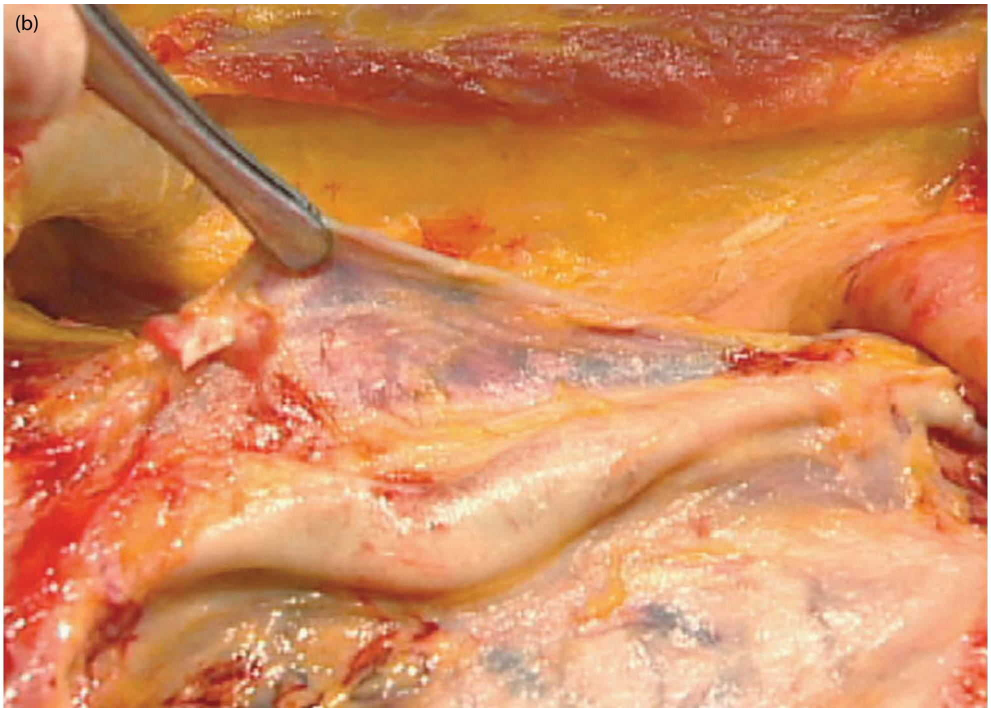


Figure 7.54 (a and b) Jugular vein relationships. The jugular vein is the collapsed, thin-walled vein displayed by the forceps. The jugular veins are easily compressed by choking, classic ligature hanging, or strangulation. The compressed jugular veins significantly limit venous return of blood from the veins of the head and neck to the heart. Blood is pumped into the brain, but cannot return to the heart. The result is hypoxia of the brain, unconsciousness, and death.

Figure 7.55 Hanging by ligature. This victim of a suicidal hanging was suspended by the depicted rope. The impression left by the ligature, or ligature furrow, shows that the ligature compressed the area of the jugular vein, not the trachea; still, death by asphyxia resulted.

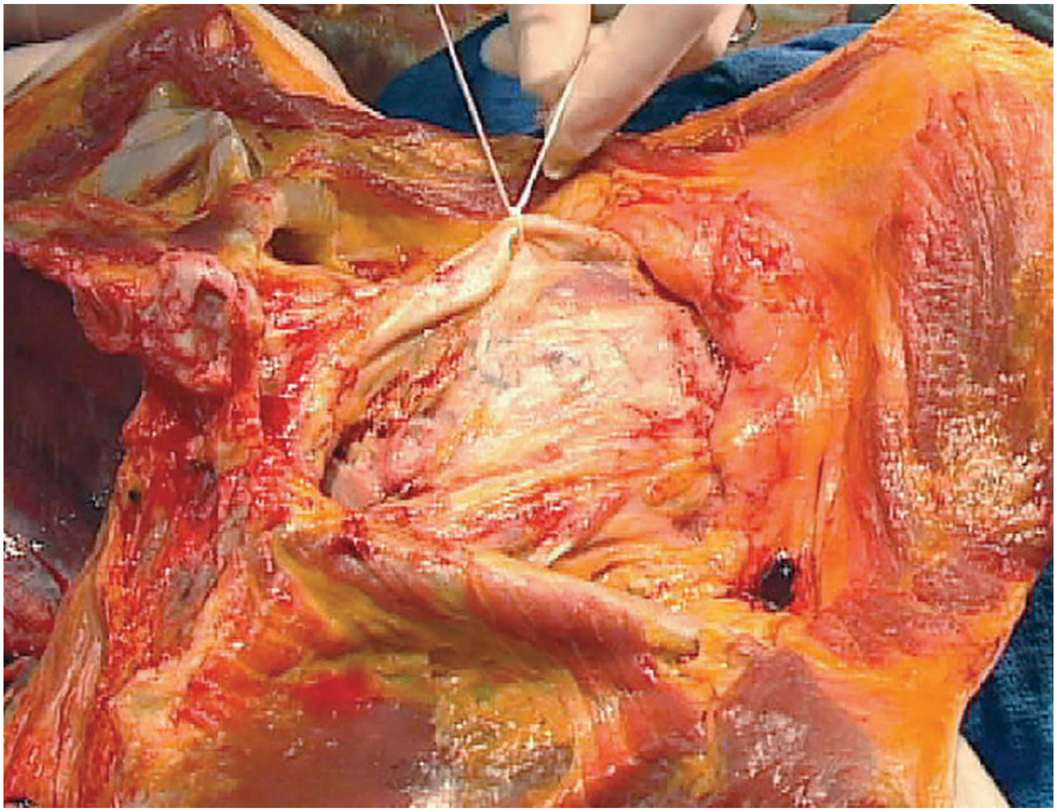


Figure 7.56 Carotid tie. The carotid is tied to help the embalmer find the vessels for the injection of tissue preservatives.

CHAPTER 8

INDIVIDUAL ORGAN EXAMINATION

Generally, the pathologist examines each organ and tissue from the outside to the inside, first observing its "gross" or macroscopic appearance, then dissecting it, and finally studying its microscopic features. The objectives are to:

- Examine and observe the diseases or injuries of each organ or tissue in a systematic, complete fashion.
- Make diagnoses and form opinions about the etiologies of the diseases or injuries. The examination is made of the gross organ or tissues, selecting samples of areas showing disease or injury, and submitting that tissue for later microscopic examination (see Chapter 10).
- Describe the diseases, disorders, or injuries, and make a record of these observations. This allows other experts to review the report and to draw independent conclusions about the data provided.
- Document pertinent diseases or injuries using photography or other media.
- Preserve pertinent tissues either in a fixative or paraffin, so that additional studies can be performed later. For example, hemorrhagic soft tissue of the neck is often retained in strangulation cases.

The reader should follow the photographs and text in Figures 8.1 through 8.90 to be taken through the individual organ examination. (See Videos 8.1 through 8.6.)

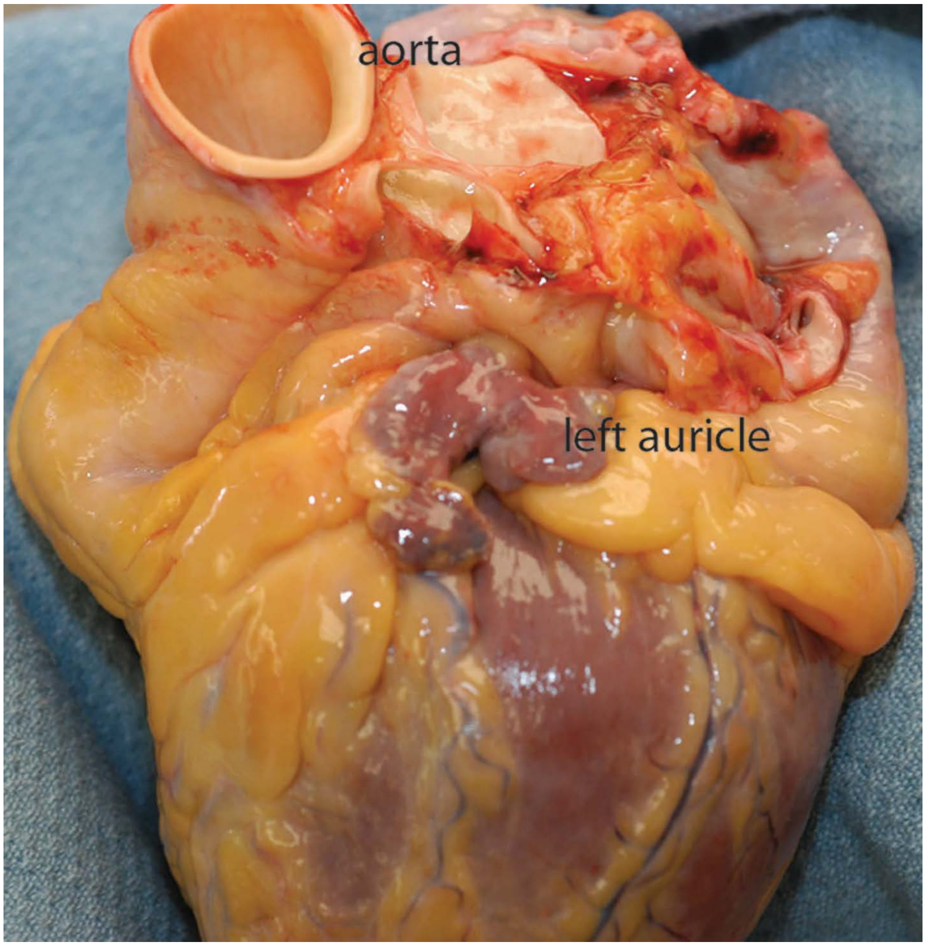


Figure 8.1 Anterior view of the heart. The normal heart is viewed after its removal, showing the open aorta and smaller auricle, or "ear," of the left atrium.

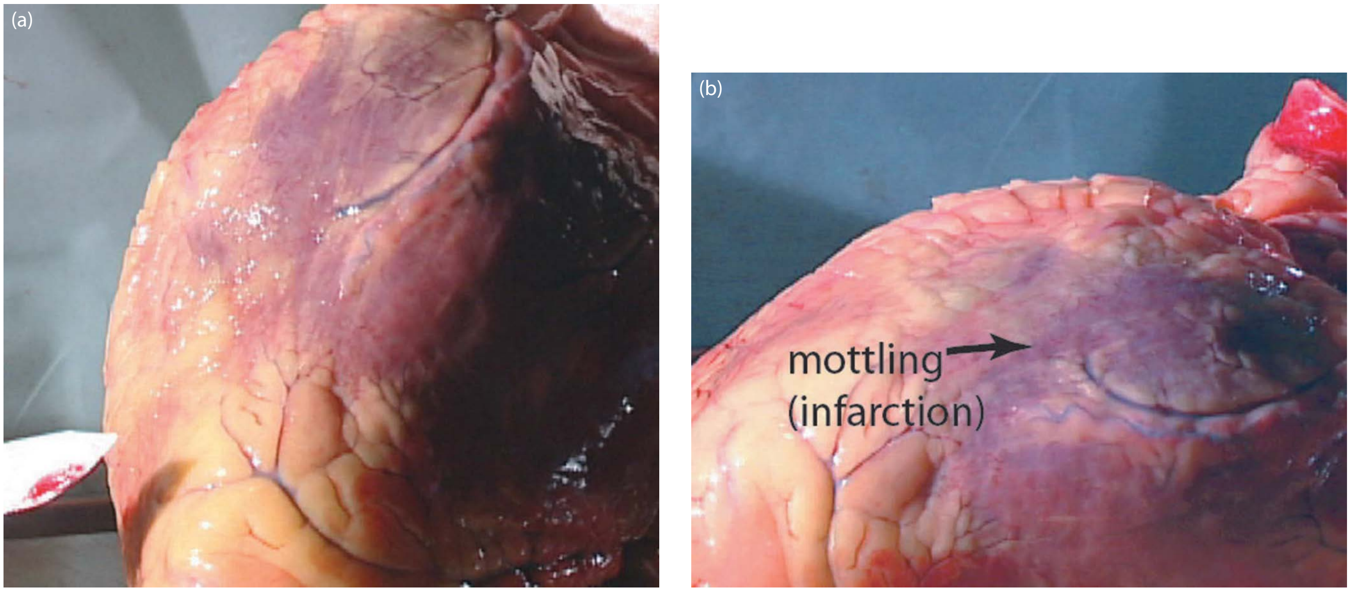


Figure 8.2 (a and b) Mottling due to myocardial infarction. The outside of the heart, or epicardium, is examined, revealing a discoloration or mottling, as shown by the arrow (also see Figure 8.17a and 8.17b).

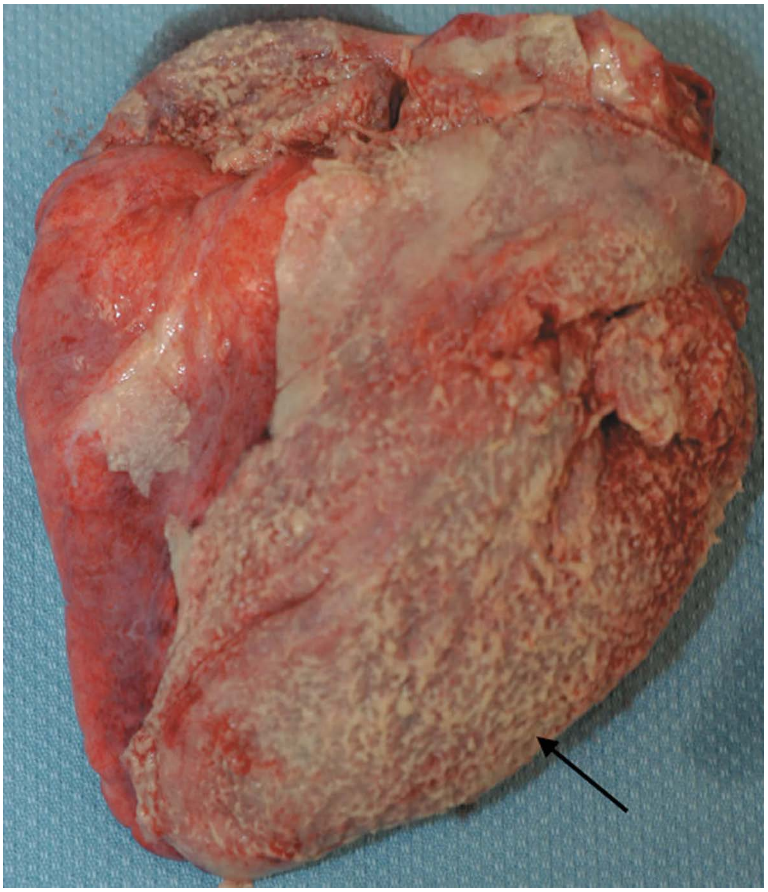


Figure 8.3 Pericarditis. Bacterial inflammation of the heart leaves a "crust," or exudate, often referred to as "bread and butter" pericarditis.

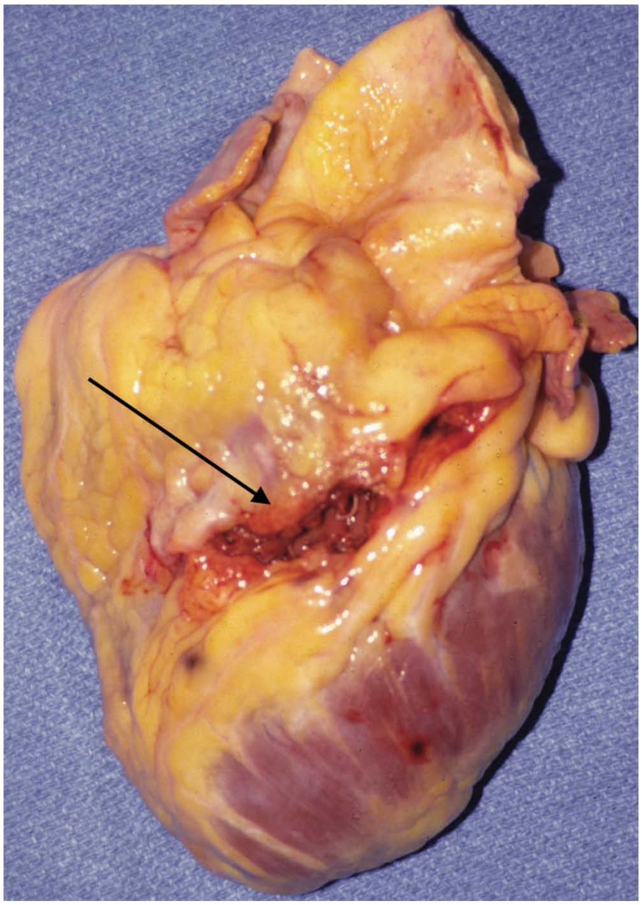


Figure 8.4 Cardiac laceration. A severe blunt trauma to the chest, such as that occurring in a high-speed motor vehicle crash, can cause cardiac laceration.

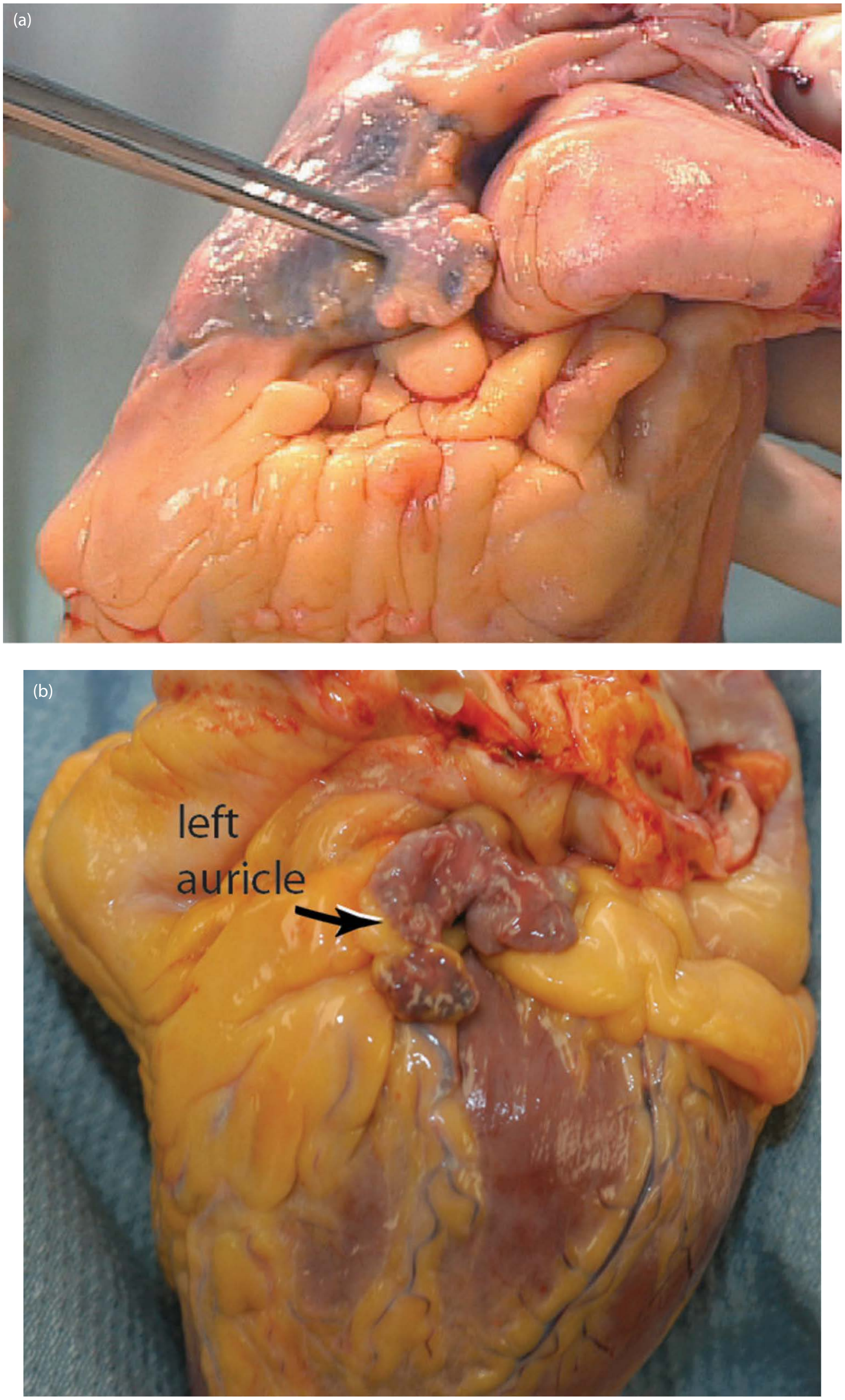


Figure 8.5 (a) Right auricle. The heart has two auricles, or "ears"—a right and a left. The right auricle is shown by the forceps. **(b) Front view of the heart.** The left auricle is shown by the arrow. When the coronary artery anatomy is normal, the right main coronary artery can be found by lifting up the right auricle of the right atrium. The left main coronary is found under the left auricle.

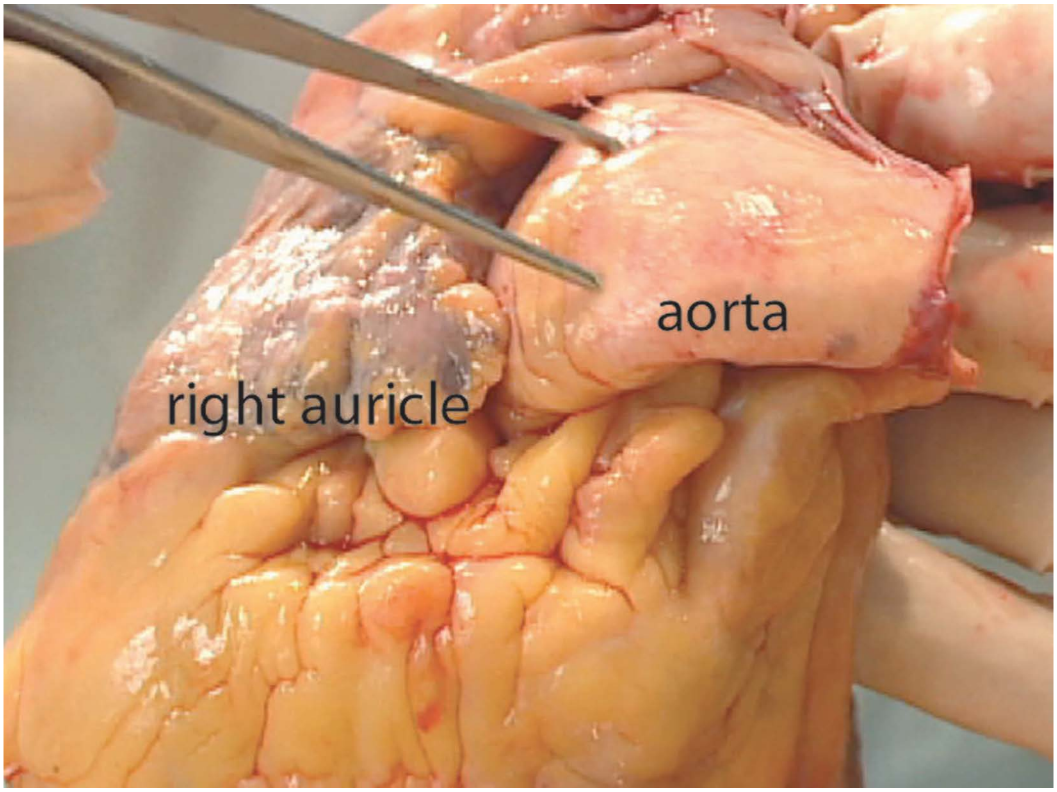


Figure 8.6 Aorta and right atrial auricle. The aorta is the curved structure indicated by the forceps.

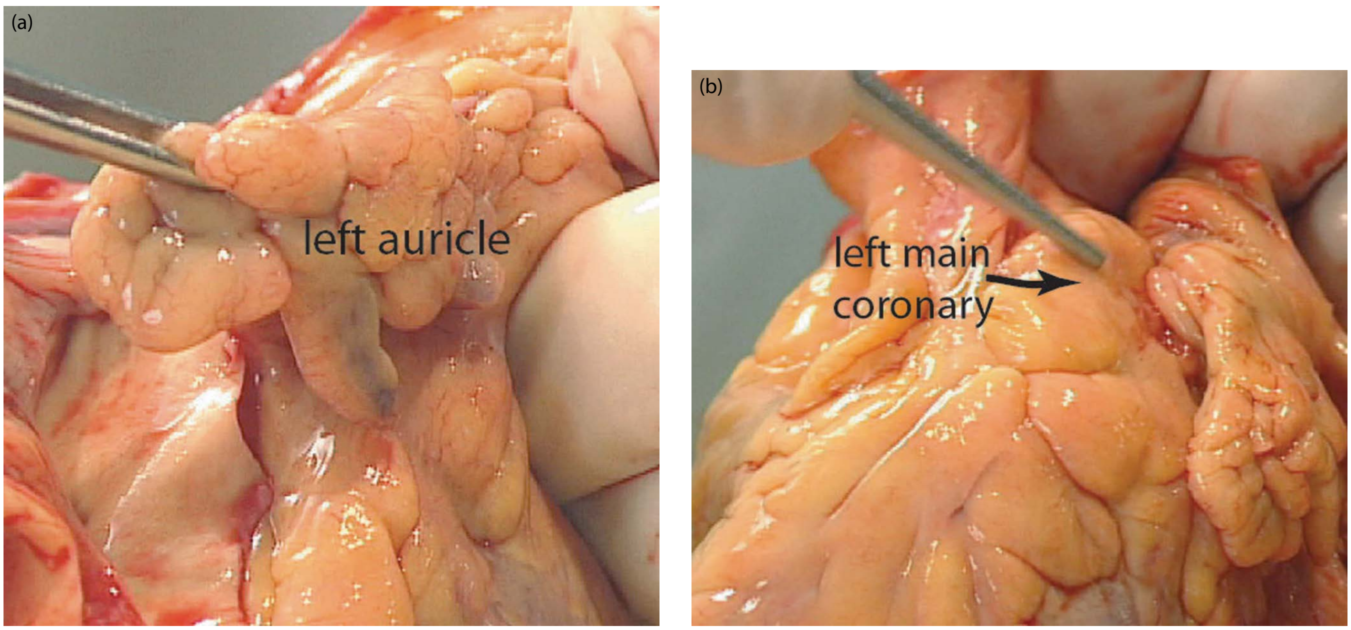


Figure 8.7 (a) Left auricle. The left auricle is held up by the forceps. The left auricle is somewhat smaller than the right. **(b) Left main coronary artery relationships.** The left main coronary artery runs beneath the auricle, generally the area indicated by the forceps.

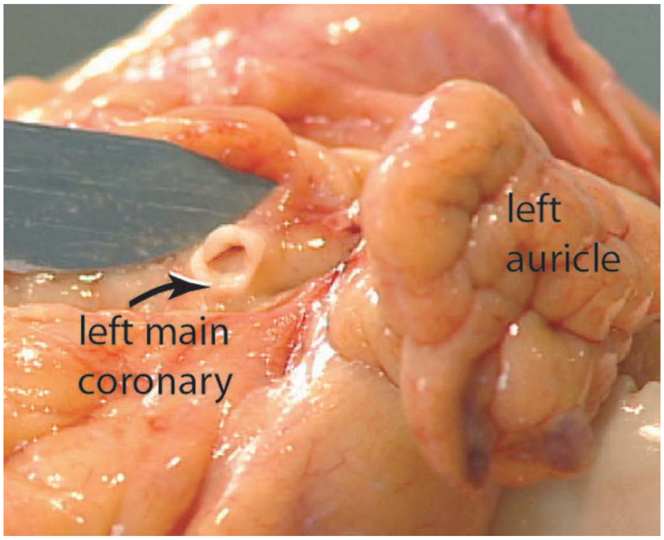


Figure 8.8 Cutting the left main coronary artery. The left auricle is lifted and cuts are made into the left main coronary artery and the left anterior descending branch of this artery. In this method, cuts are made to the artery in order to look for atherosclerotic plaque, thrombi (blood clots), or aneurysms (ballooning of the vessel wall).

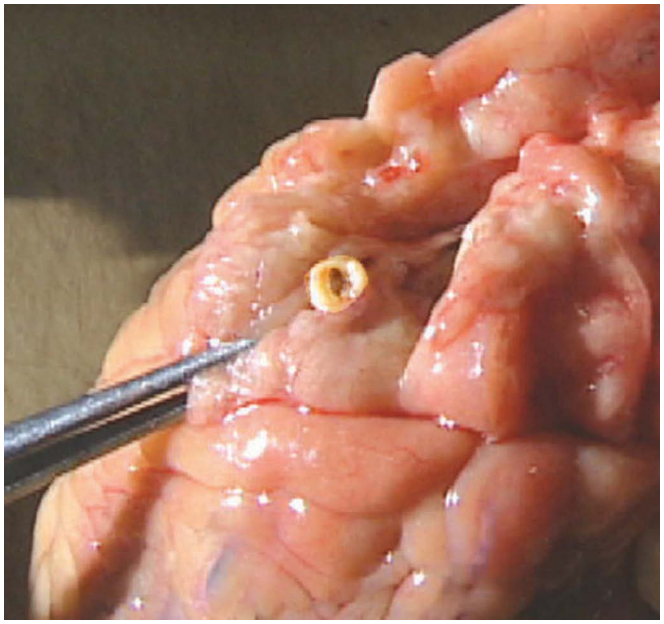


Figure 8.9 Left coronary artery thrombosis. This cut of the left main coronary artery shows nearly complete occlusive atherosclerosis. A small, dark thrombus occludes the lumen (seen near the tip of the forceps). Occlusion of the artery results in loss of blood flow to the region of the left ventricle of the heart that the artery supplies. Lack of blood flow results in lack of oxygen (hypoxia) to the tissues. If the thrombus or blocking plaque continues to occlude the vessel wall, the lack of oxygen results in cell death. Widespread cell death in the heart results in myocardial infarction, commonly known as a heart attack.

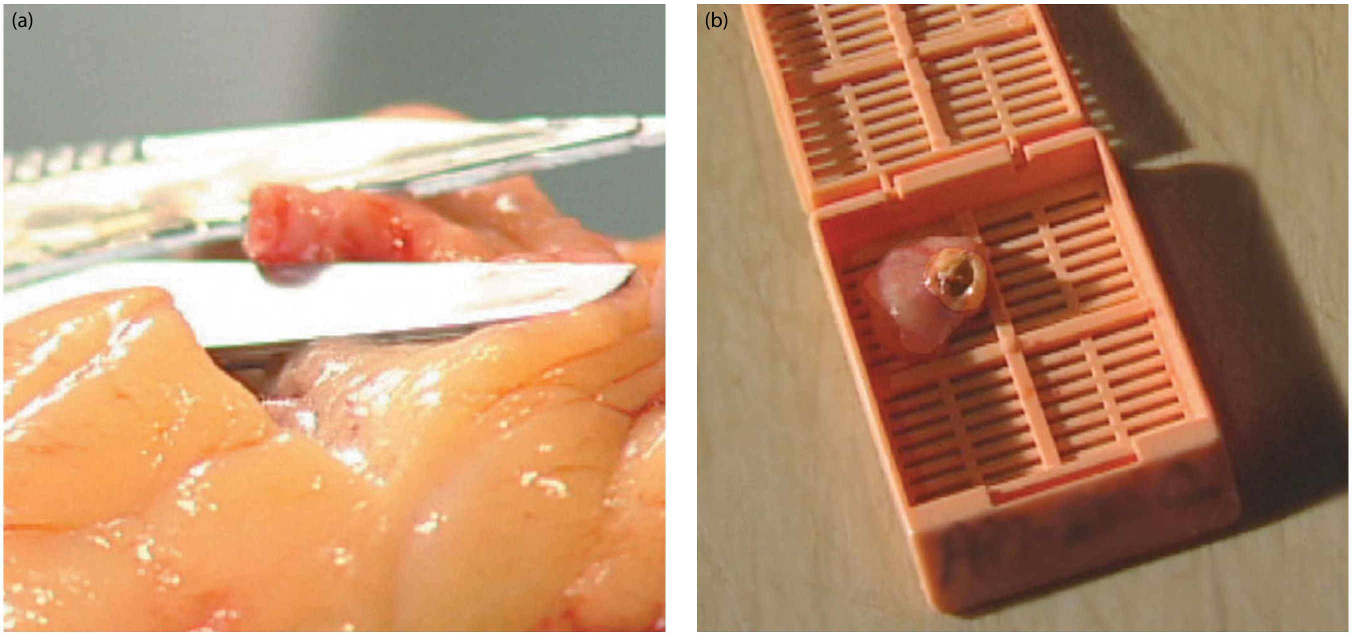


Figure 8.10 (a) Cutting a coronary artery. This artery is difficult to cut because it is affected with atherosclerosis. **(b) Placing the section for microscopic examination.** A section of the artery is cut and placed in a histology cassette. The tissue will be processed, cut into thin sections, placed on glass slides, and stained for review under the microscope (see Figure 10.3a). In the center of the specimen is a dark-colored thrombus.

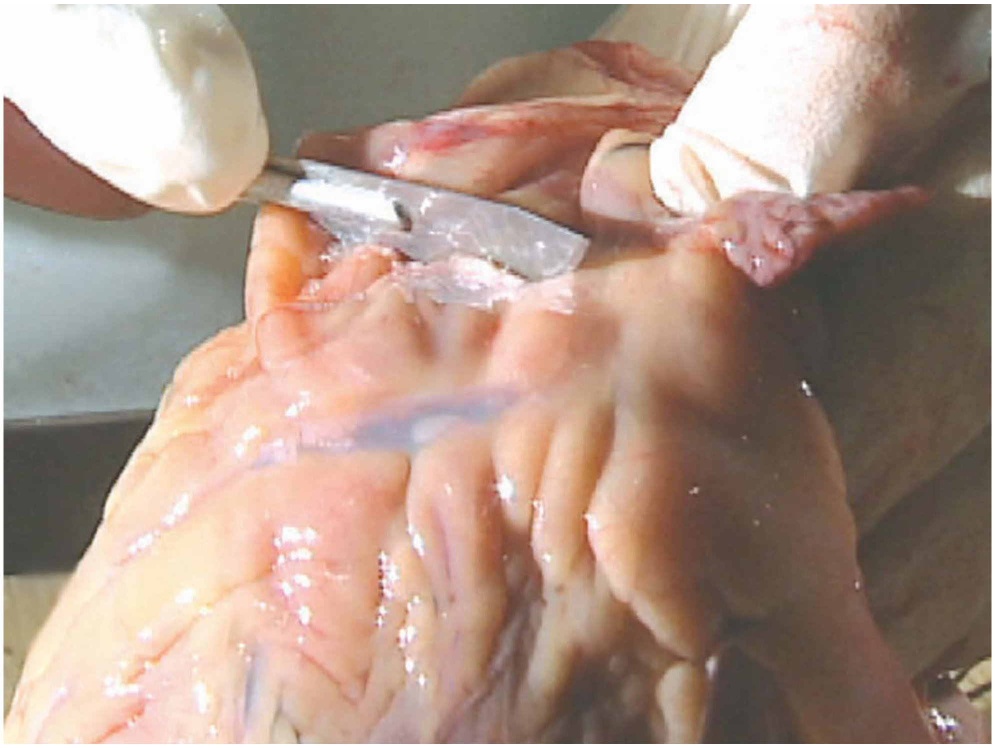


Figure 8.11 Cutting the left anterior descending coronary artery. A series of cuts are made along the entire length of the left anterior descending branch of the left coronary artery, usually the largest coronary artery of the heart. The artery must be examined from its origin, called the coronary ostium, so as not to overlook a focal thrombus or coronary disease.

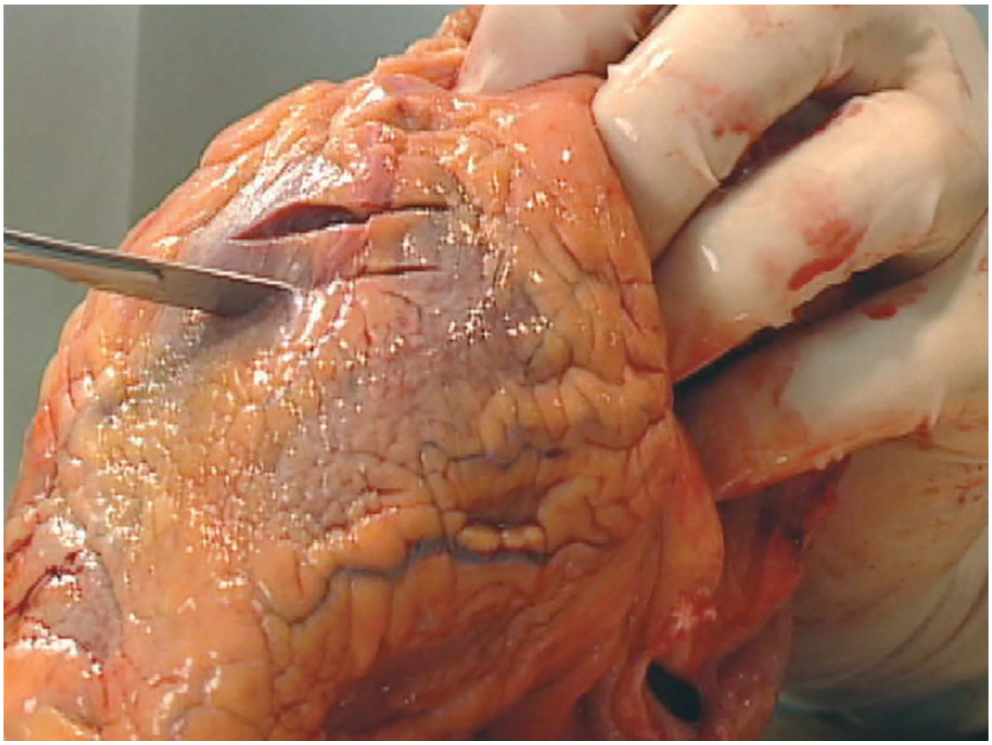


Figure 8.12 Cutting the first diagonal branch of the left coronary artery. Smaller left coronary artery branches are also examined.

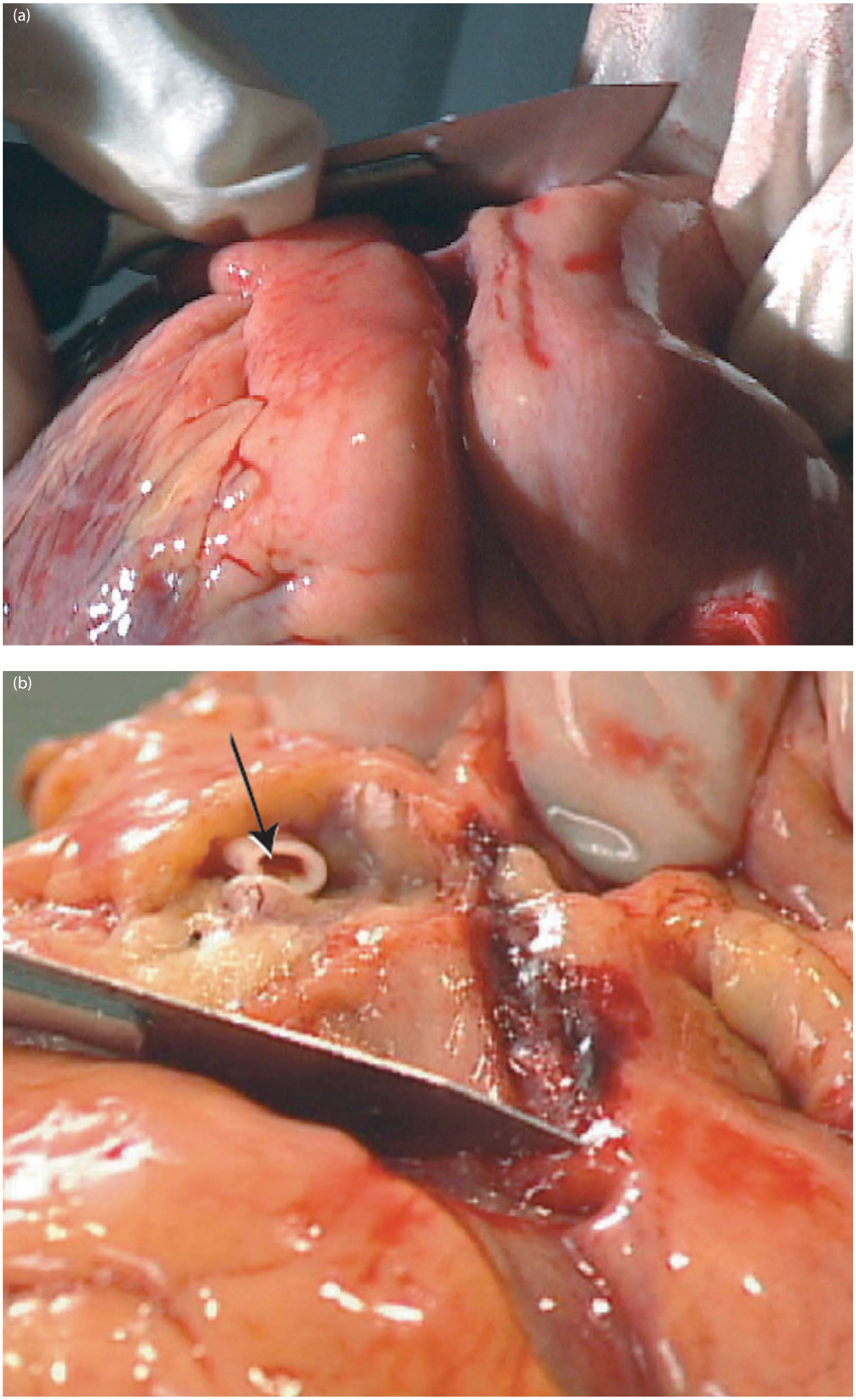
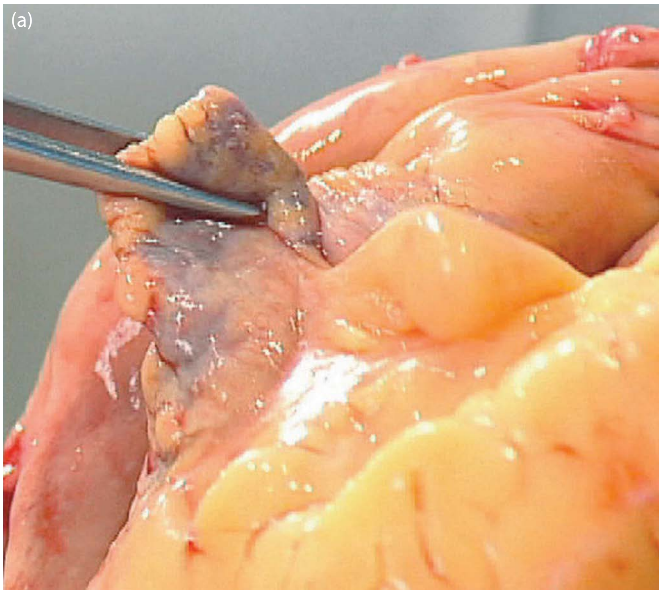


Figure 8.13 Cutting the circumflex coronary artery. (a) The circumflex artery usually branches off the left main coronary artery. More rarely, it can originate from the aorta. The circumflex artery turns sharply left, running above the upper margin of the left ventricle of the heart. **(b)** The cut artery is shown by the arrow.



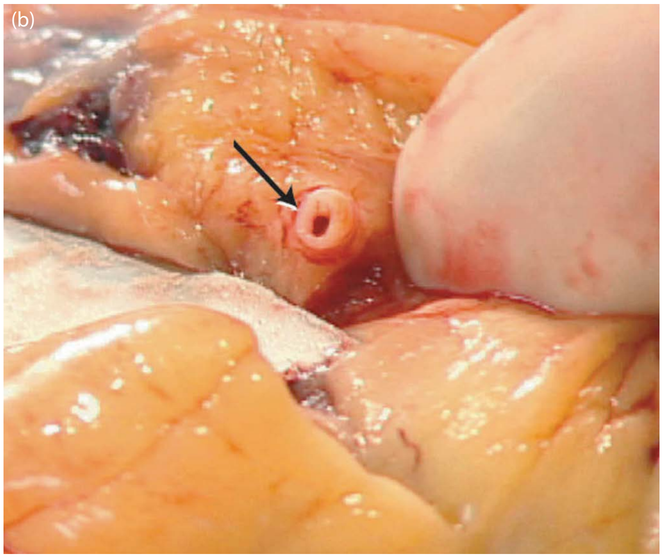


Figure 8.14 Cutting the right coronary artery. (a) The right auricle is shown by the forceps. **(b)** As the cut is made, a mostly patent right coronary artery cross-section is visible (arrow). This artery is larger than the circumflex artery in most people because it supplies the posterior septum (back of the heart).

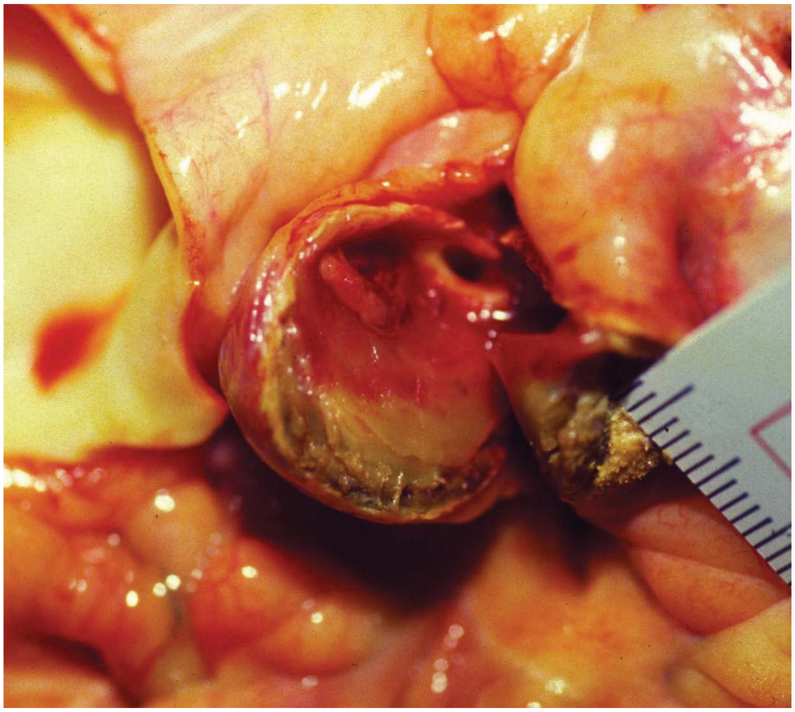


Figure 8.15 Coronary artery aneurysm with atherothrombotic occlusion. The cross-section of this coronary artery shows a dilated (aneurysmal) artery filled with atherosclerotic plaque and thrombus. This person was the victim of a motor vehicle crash, and the heart disease was not related to the crash. This case illustrates that even with severe coronary artery disease, many people can function relatively normally. The scale shown is in centimeters.

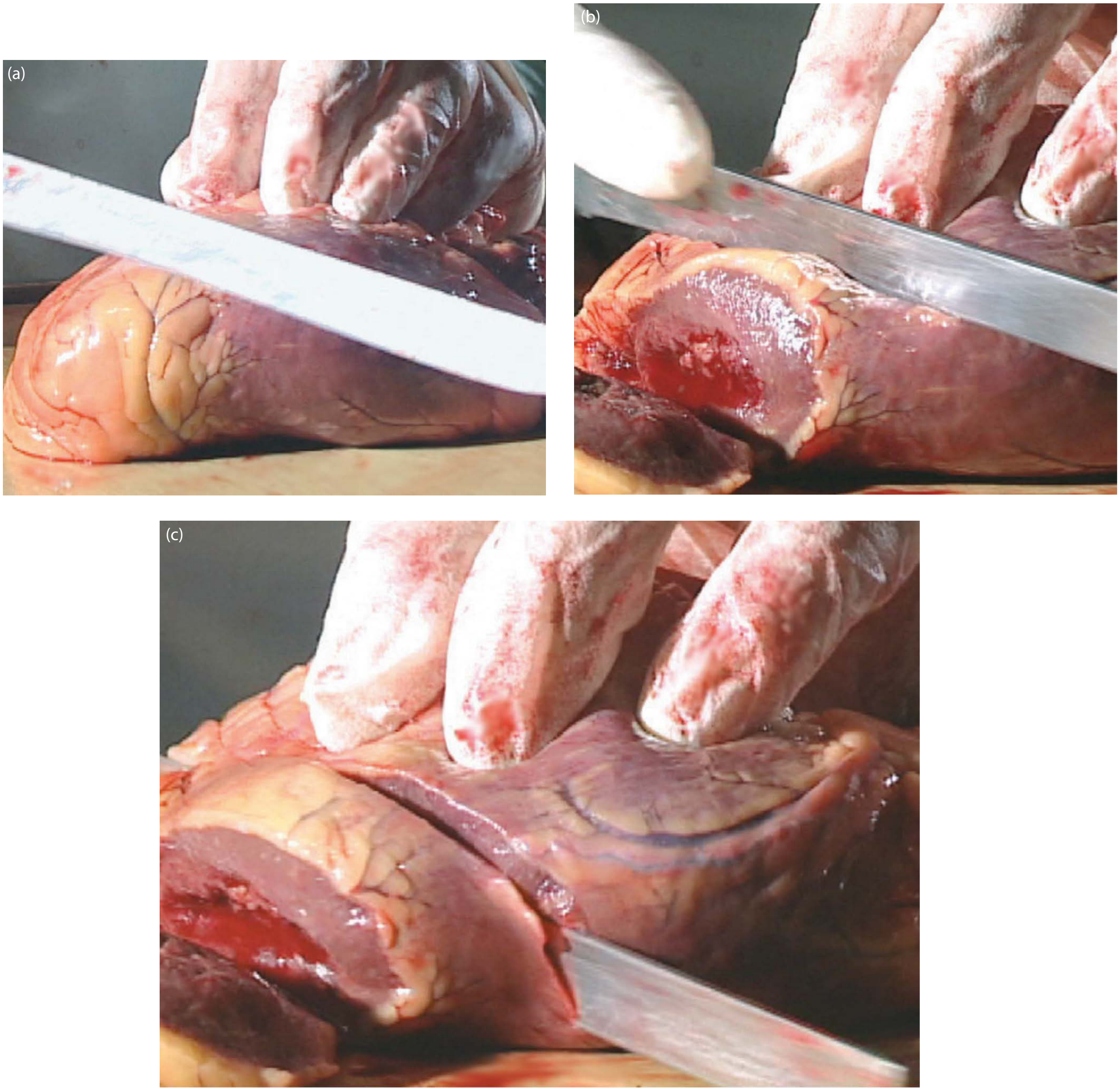


Figure 8.16 (a–c) "Breadloafing" the ventricles of the heart. The heart can be opened in many different ways. For example, the heart is cut in the direction of blood flow when developmental abnormalities are seen. Since myocardial infarction is suspected in this heart, cuts will be made in the ventricles perpendicular to the long axis of the heart, referred to as "breadloafing."

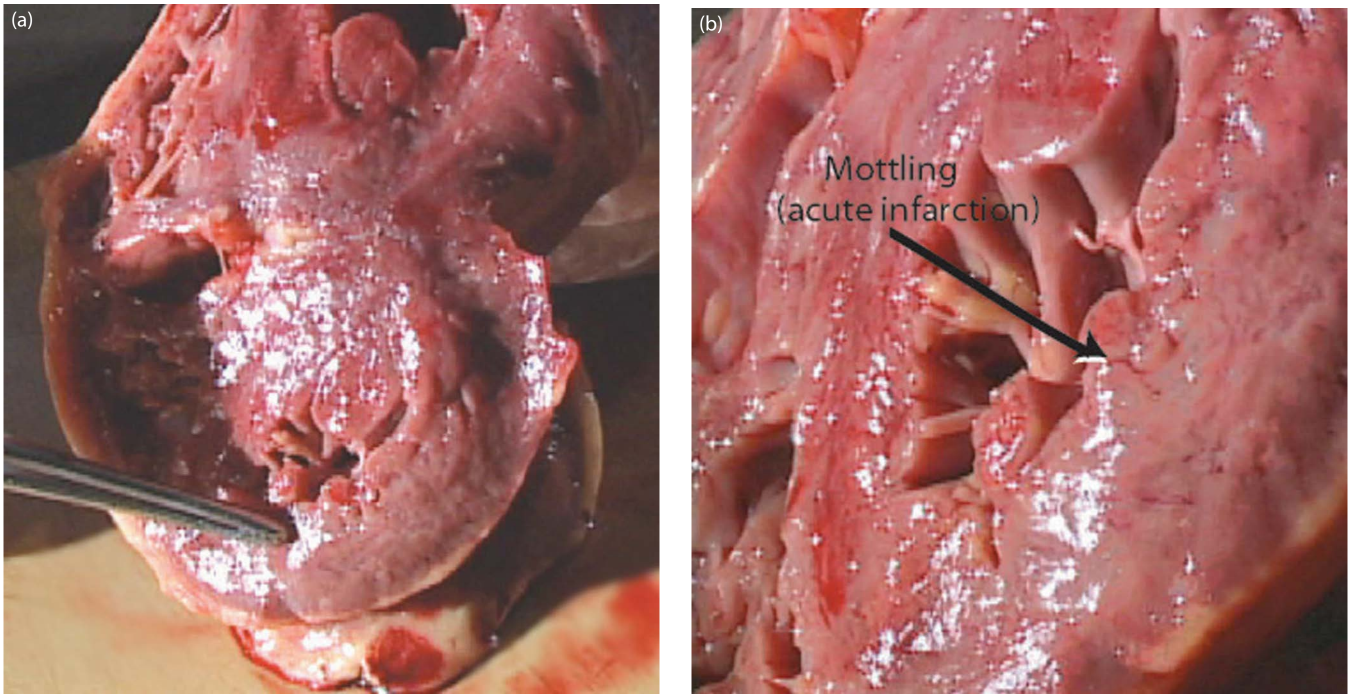


Figure 8.17 Mottling of cut myocardium due to acute myocardial infarction. This myocardial section shows mottling in the lateral left ventricular wall, suggesting early myocardial infarction. Infarction will be confirmed by examining tissue sections with the microscope (also see Figures 8.2a, 8.2b, 10.2a, and 10.2b).

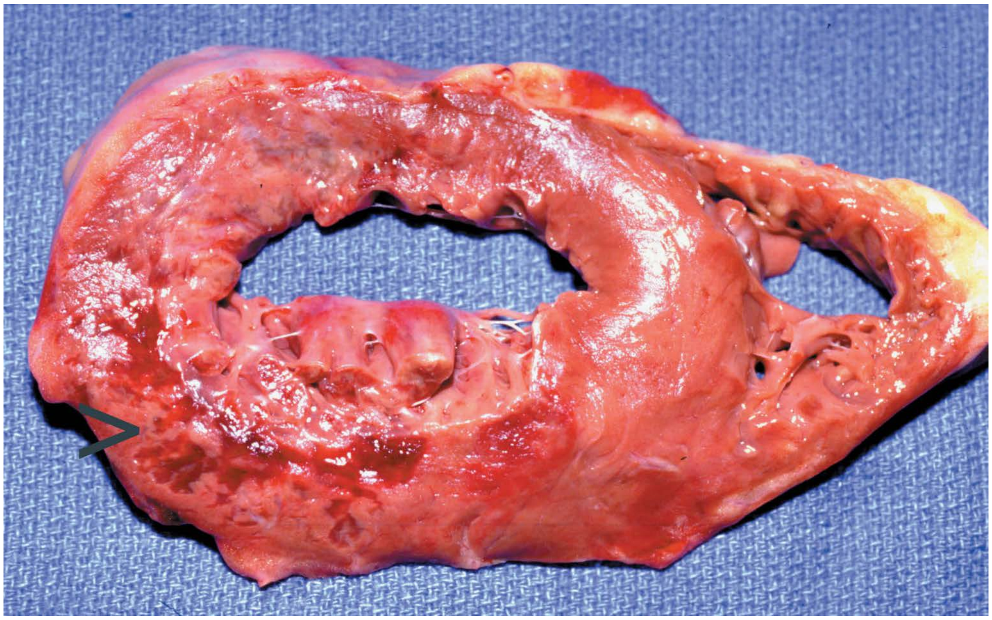


Figure 8.18 Acute myocardial infarction. Marked mottling can be seen on the anterior left ventricular wall, at the bottom of the figure.

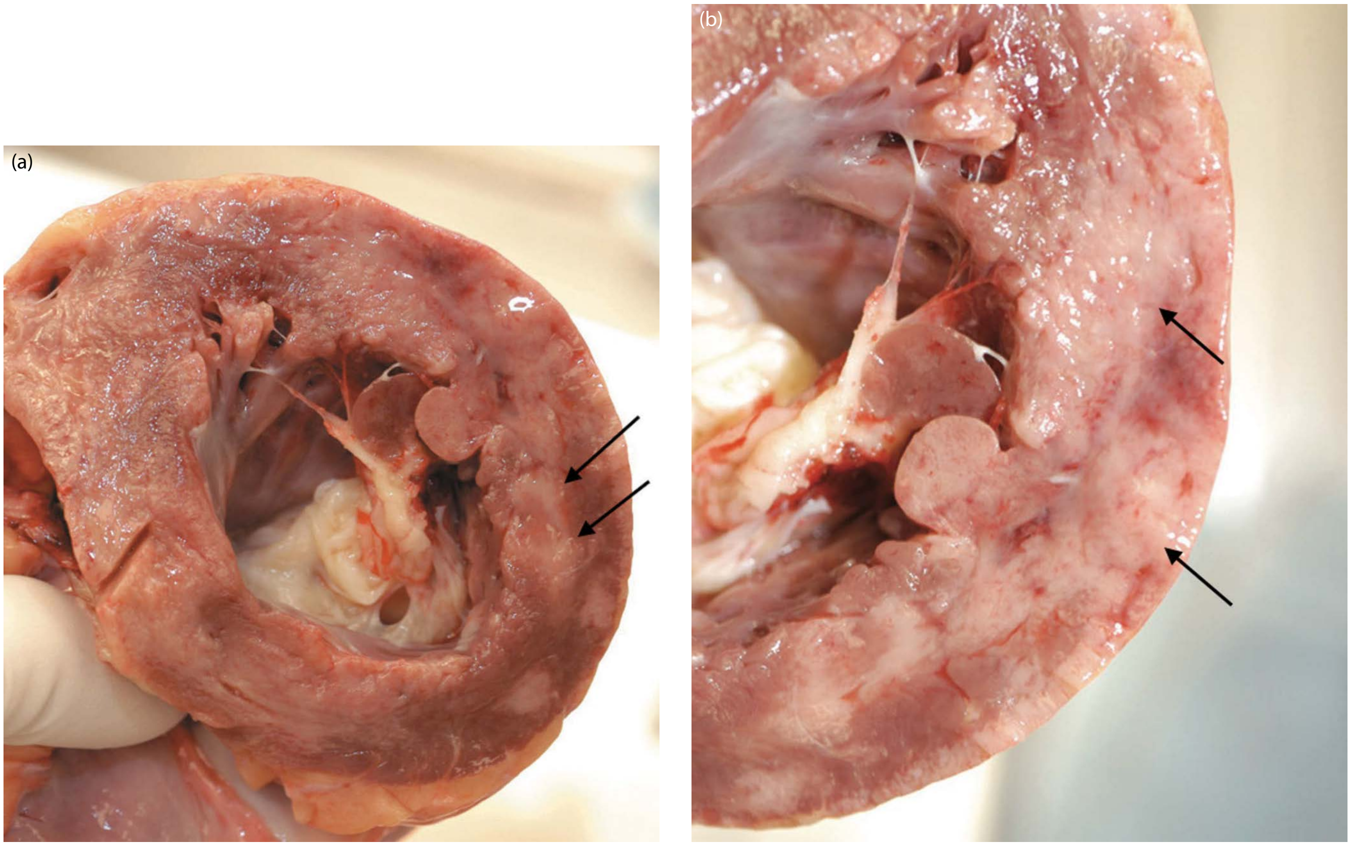


Figure 8.19 (a and b) Myocarditis. The cross-section of this heart shows blotches and streaks of white myocarditis throughout the normal brown myocardium. This patient had severe myocarditis, resulting in heart failure and death. The causes of myocarditis can be bacterial (Lyme disease), fungal, viral (Coxsackie B virus is common), and drug reactions. The cause of myocarditis is not found in many cases (see Figure 10.4a and 10.4b for microscopic views).

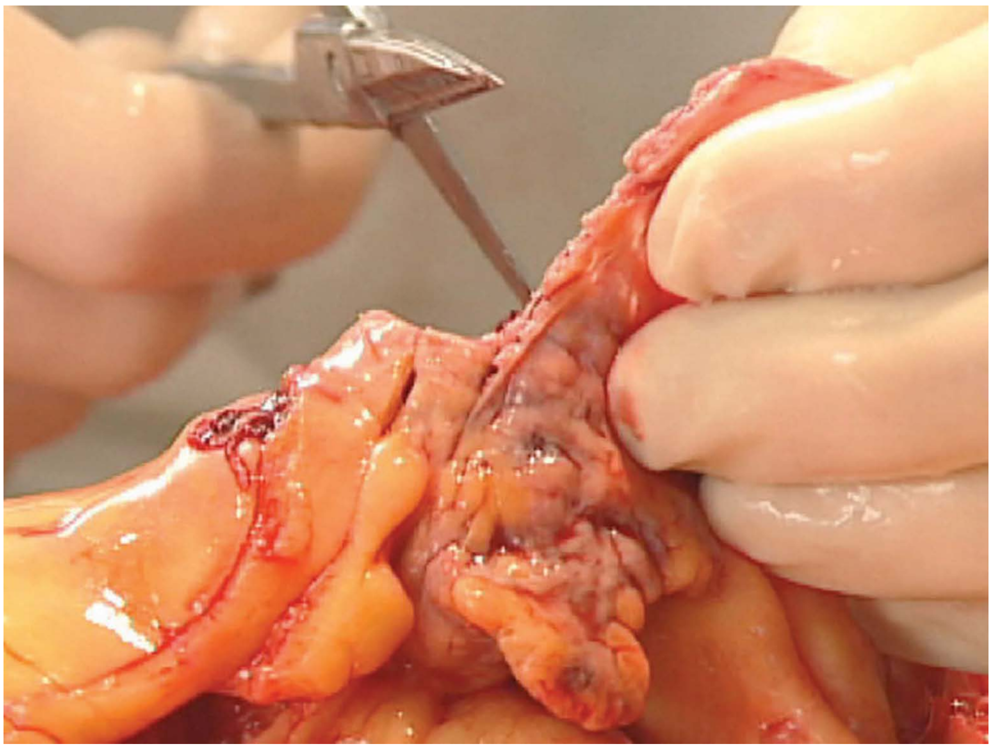


Figure 8.20 Opening the right atrium. Now that the right and left ventricles have been cut, the atria and the heart valves are opened in the direction of blood flow. Venous blood with low oxygenation is returned from the body and enters the right atrium. Blood is then pumped through the tricuspid valve to the right ventricle. From the right ventricle, blood is pumped through the pulmonic valve to the lungs for oxygenation. Oxygenated blood is returned to the heart via the pulmonic veins and enters the left atrium. Then, through the mitral valve, blood is pumped into the left ventricle. Finally, blood is pumped from the left ventricle through the aortic valve and into the aorta and systemic circulation, carrying oxygen to the tissues of the body.

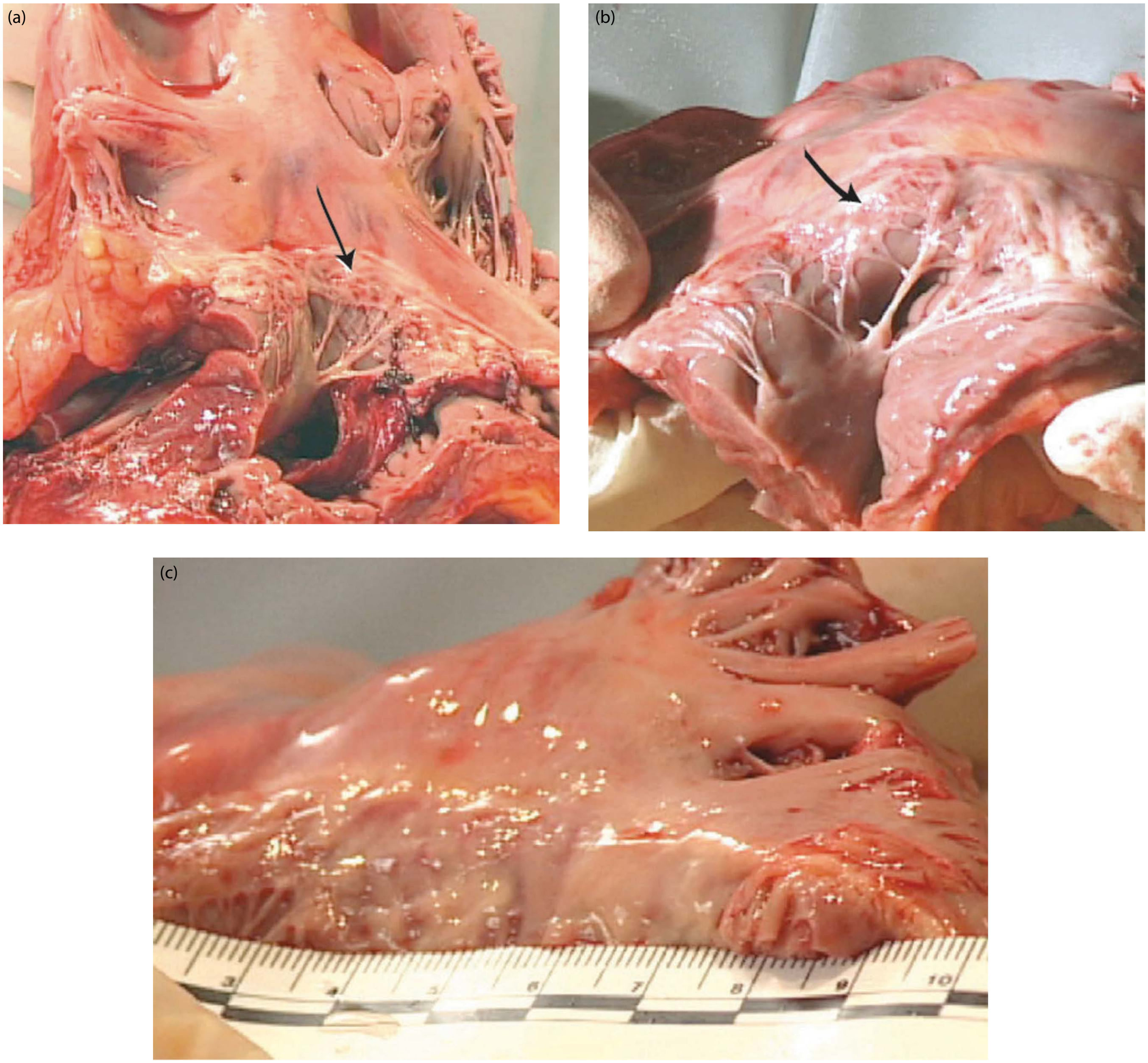


Figure 8.21 Right atrium and tricuspid examination. (a and b) The right atrium is opened (see tops of figures), exposing the tricuspid valve, shown by the arrows. **(c)** The valve circumference is measured. Enlarged hearts, especially in right heart failure, can have large, incompetent valves.

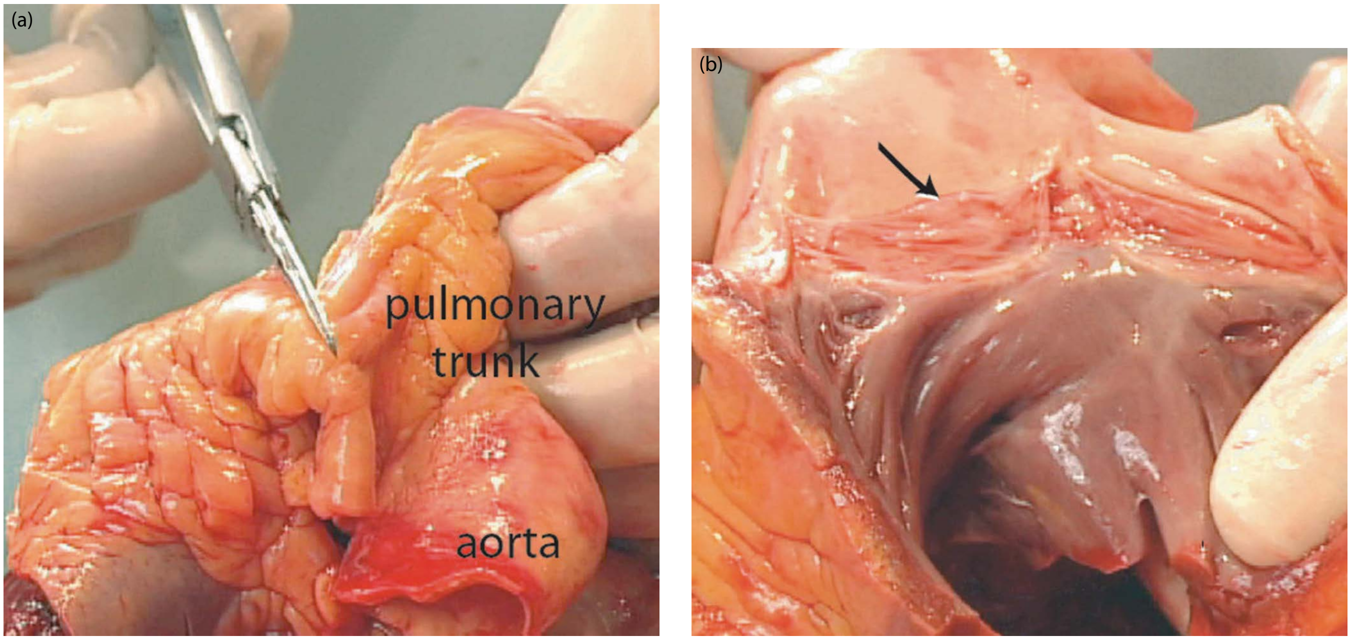


Figure 8.22 (a and b) Opening and examining the pulmonic valve. The pulmonary trunk is opened to reveal a valve with three cusps. The pathologist checks carefully for thrombi (blood clots) or vegetations.

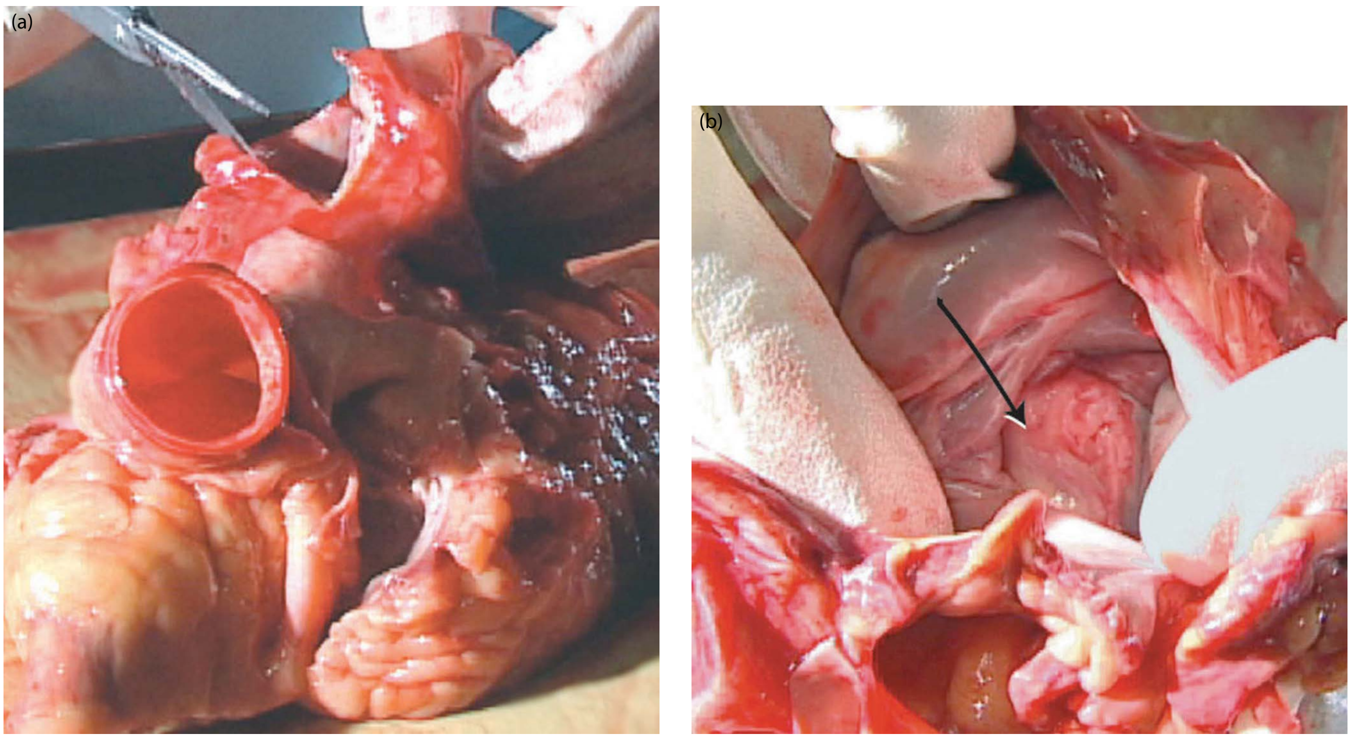


Figure 8.23 (a and b) Opening the left atrium and exposing the mitral valve. The left atrium is opened to expose the mitral valve (arrow).

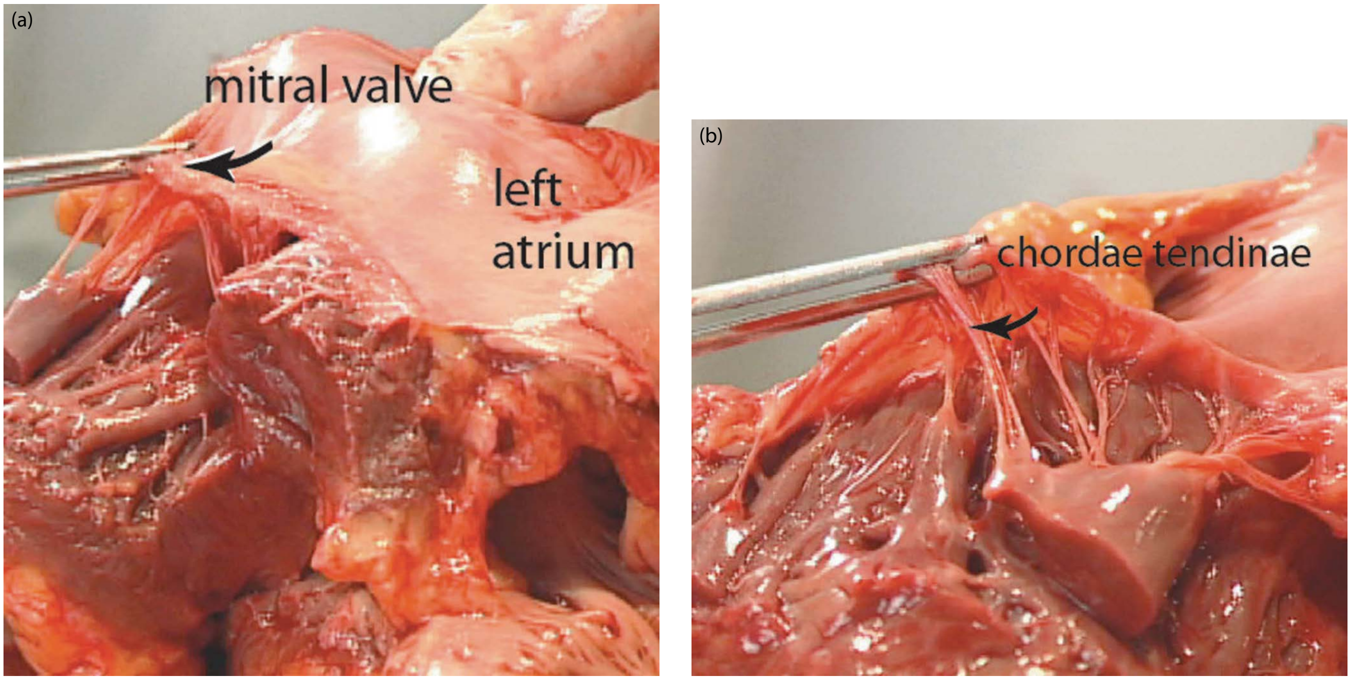


Figure 8.24 (a and b) Mitral valve opening and examination. The mitral valve is opened. The thick, tendon-like structures that tether the valve are called chordae tendinae. The mitral valve has two leaflets: anterior and posterior.

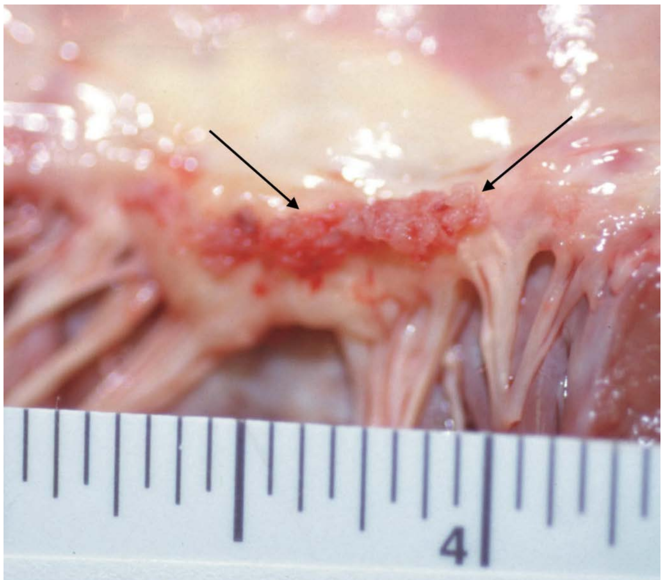


Figure 8.25 Mitral valve vegetations. The mitral valve edge is examined for vegetations. These are deposits of fibrin, clots, and bacteria in some cases that stick to the free edge of the valve leaflets. These vegetations can break loose, move into systemic circulation, and travel to organs and tissues, causing abscesses (infections) in the brain, for example (see Figure 5.15c and 5.15d).

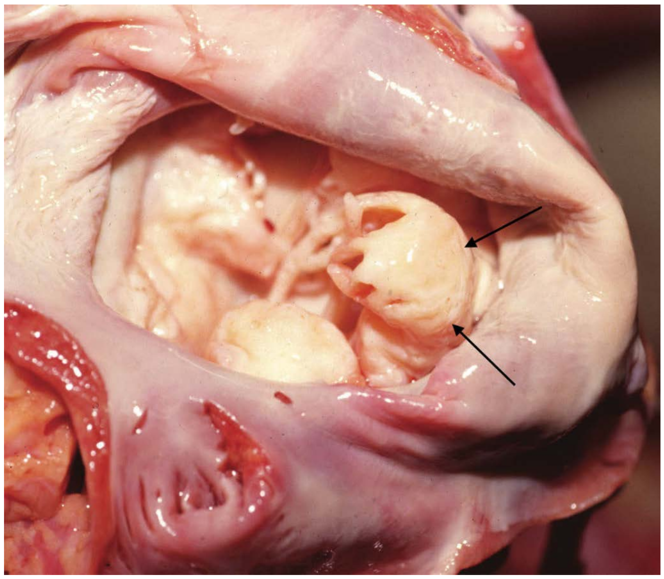
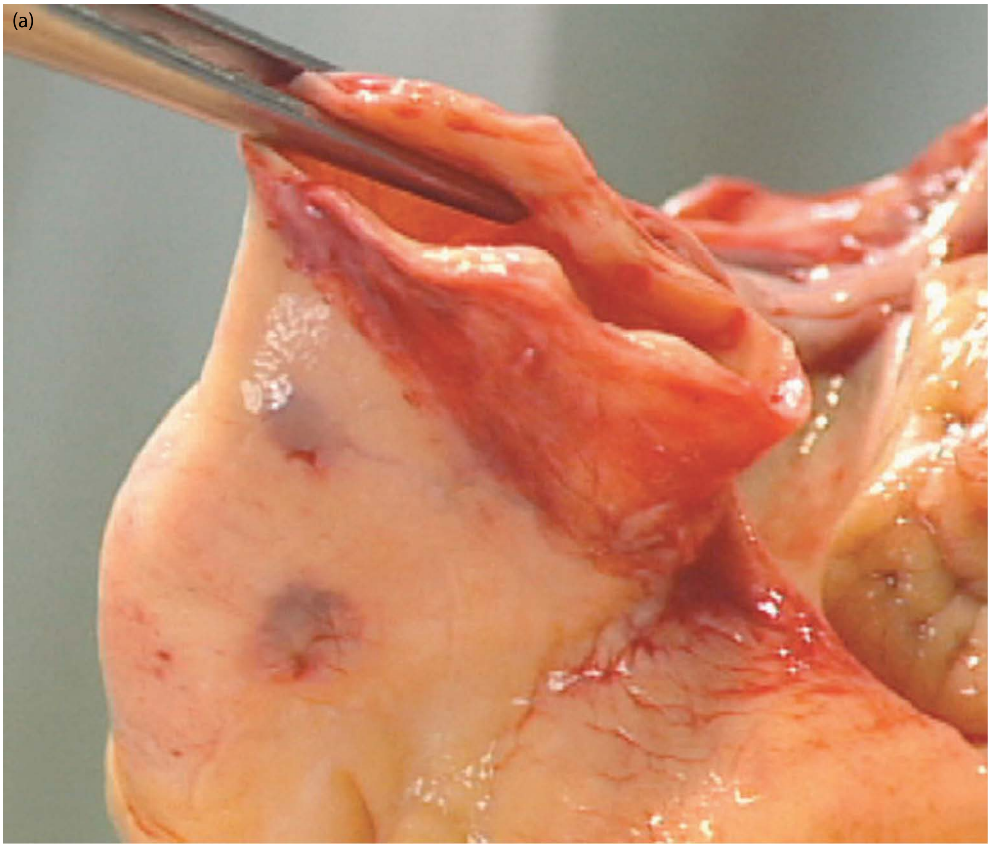


Figure 8.26 Floppy mitral valve. These valve leaflets are floppy (i.e., they are redundant and project upward when viewed from the open left atrium). This abnormal valve can cause a murmur, a condition that is associated with sudden cardiac death.



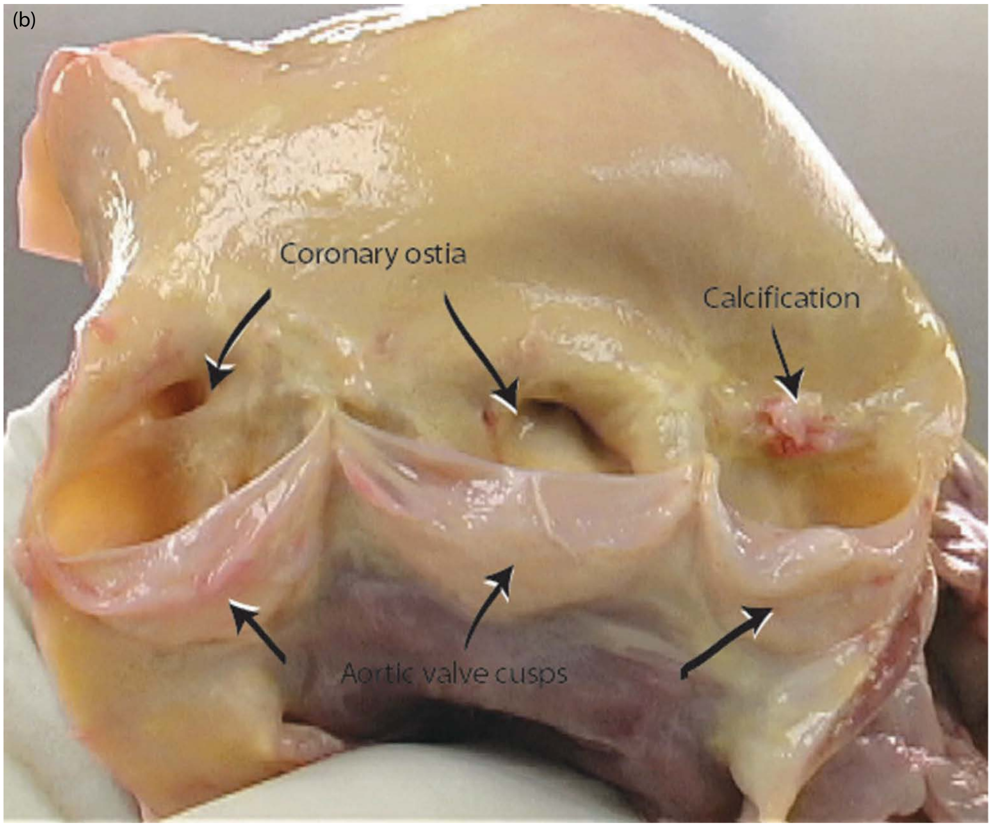


Figure 8.27 Opened aortic valve. (a) The aortic valve is opened to display three cusps. A common disorder in this region is calcification, which can cause bacteria or blood clots to form there. These bacteria or clots can travel or embolize throughout the body. **(b)** The coronary ostia, as depicted by the arrows, are the origins of the coronary arteries. The ostia are carefully examined because they are prone to occlusion by atherosclerotic plaque. The ostia should be "sighted," or looked through, to be sure that no occlusion exists.

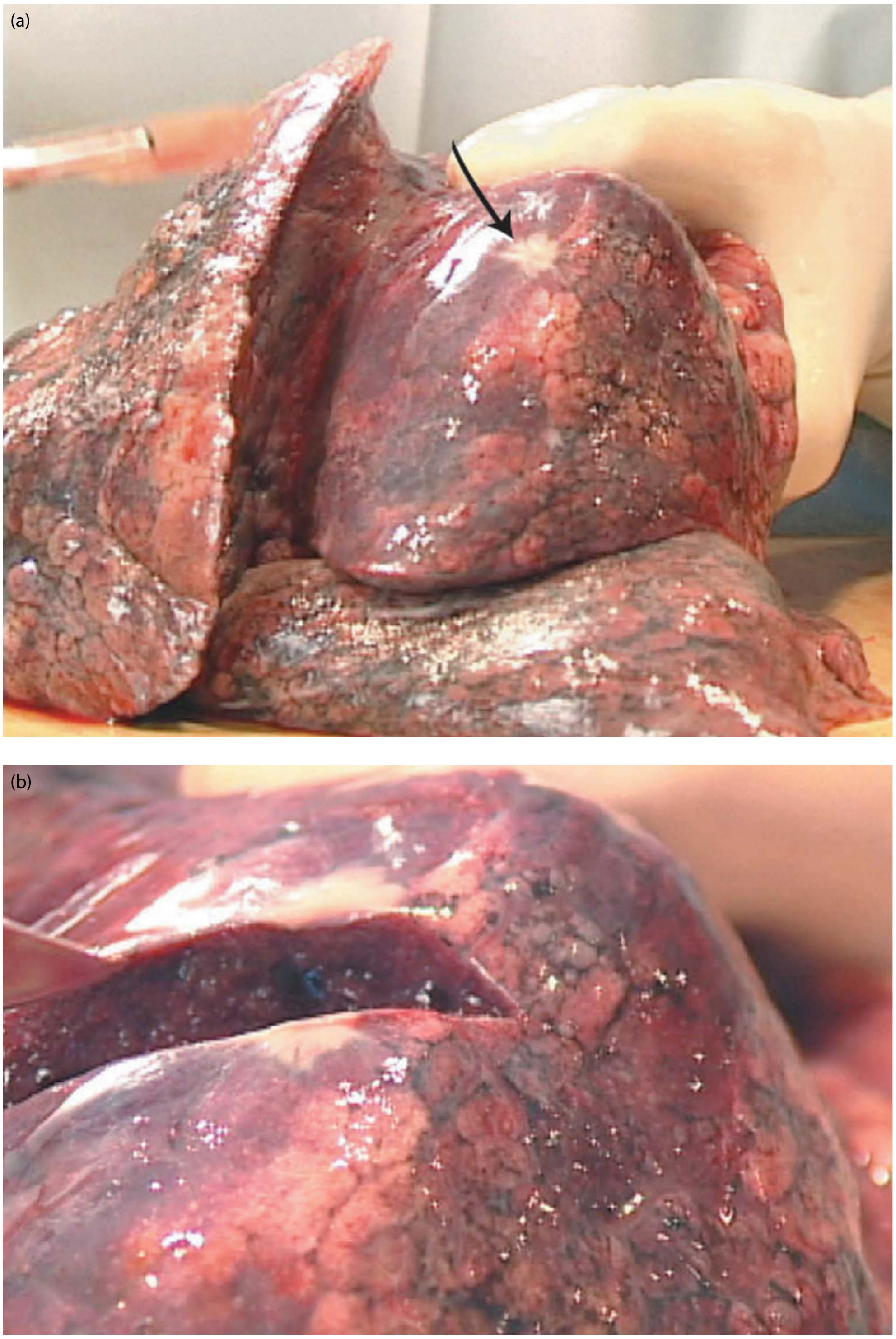


Figure 8.28 Lung examination and scar. (a) Examination of the pleura, or outer covering of the lung, reveals a whitish stellate scar (arrow). **(b)** Upon closer examination and incision, it appears to be a thin surface scar, probably the result of a healed injury or infection of the area.

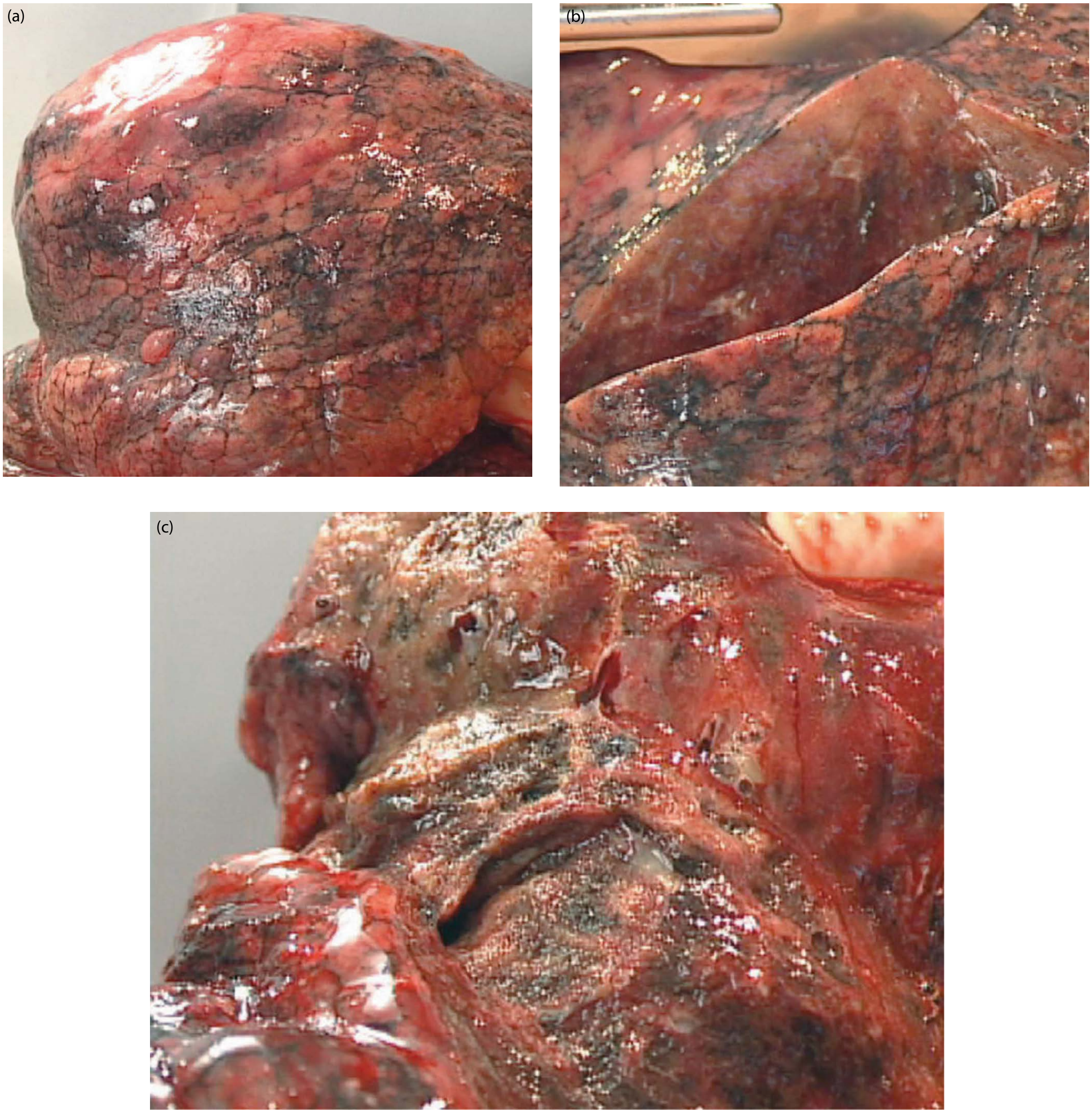


Figure 8.29 (a–c) Anthracosis of the lung. The black material peppering the pleura of the lung is referred to as anthracosis. This material is comprised mostly of inhaled carbon material. The incised lung shows that the black material permeates the lung. Tobacco smoke is a common cause of anthracosis, and smokers' lungs tend to be laden with anthracotic material. However, people can inhale carbon due to other activities, and there are many other causes of anthracosis. Coal miners and coal furnace workers, for example, can develop anthracosis.

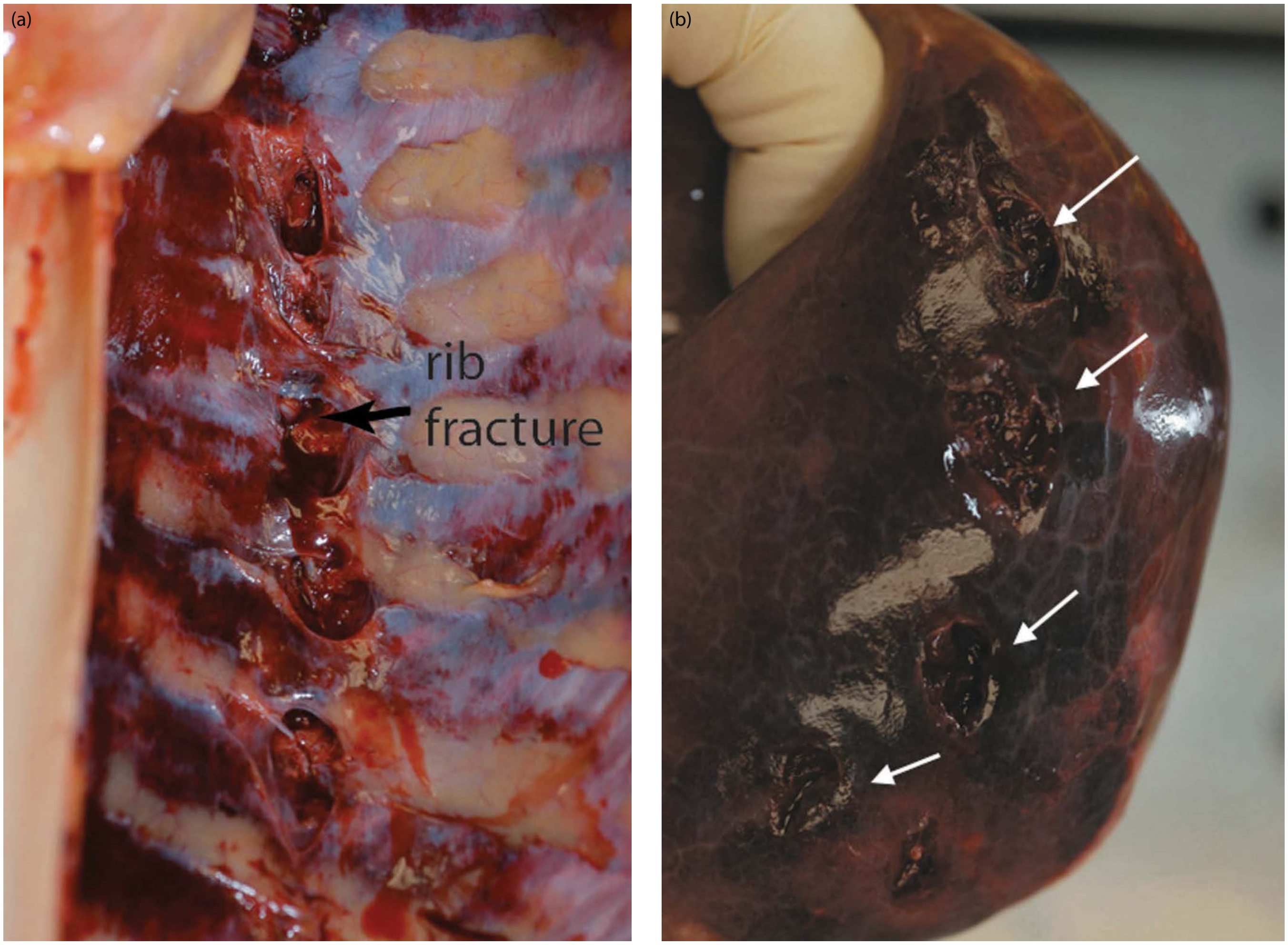


Figure 8.30 Rib fractures and corresponding lung lacerations. **(a)** The chest, ribs, and underlying lungs are susceptible to significant blunt trauma, such as that experienced in a motor vehicle crash. **(b)** The rib fractures in **(a)** are responsible for these regular, periodic lacerations of the lung.

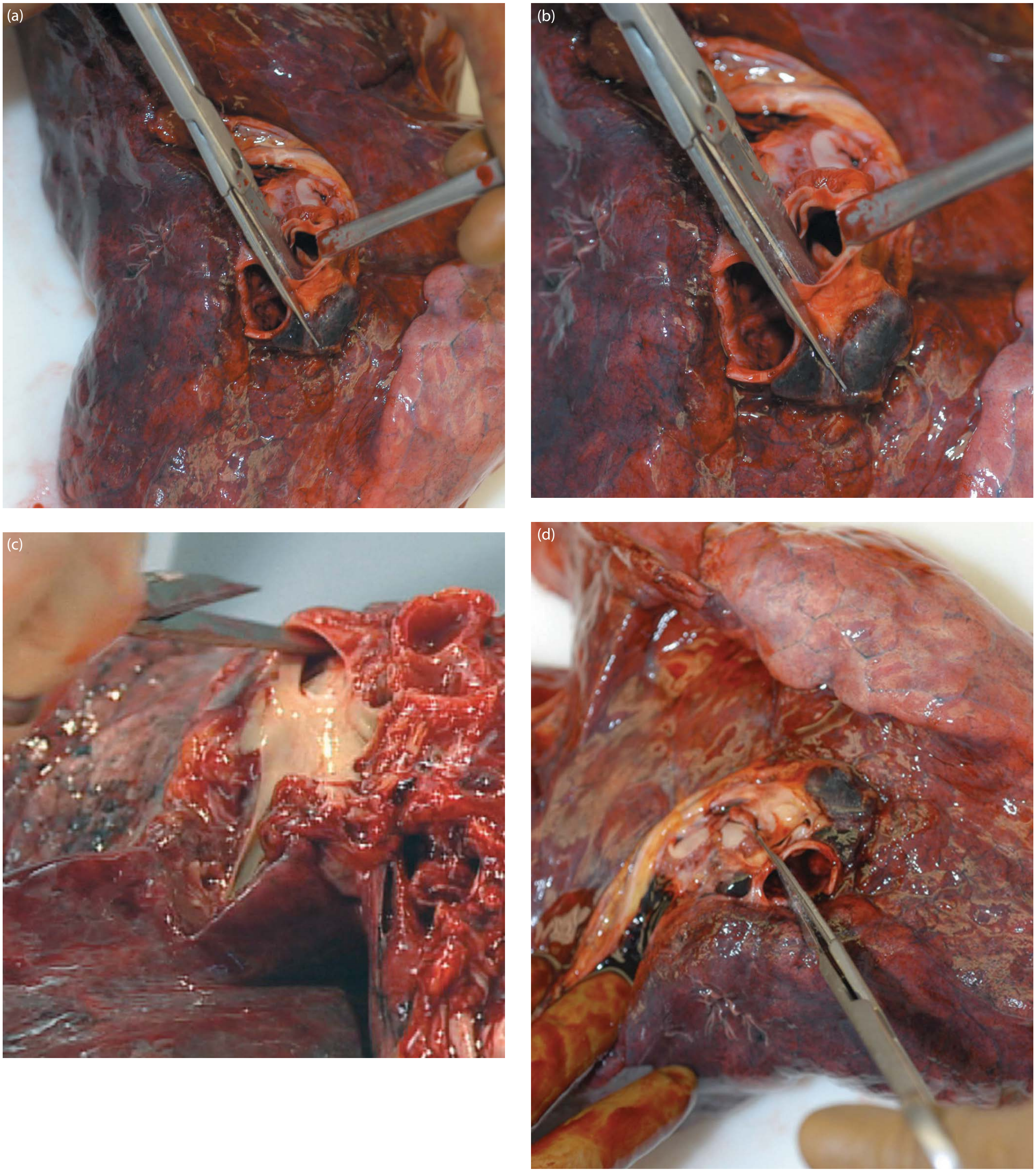


Figure 8.31 (a–d) Dissection of the pulmonary arteries. Starting at the hilum, or attachment point of the lung, the main bronchi are opened to look for inflammation and tumors, among other things. The pulmonary arteries and branches are opened to search for emboli. The lymph nodes at the hilum can be examined at this time as well.

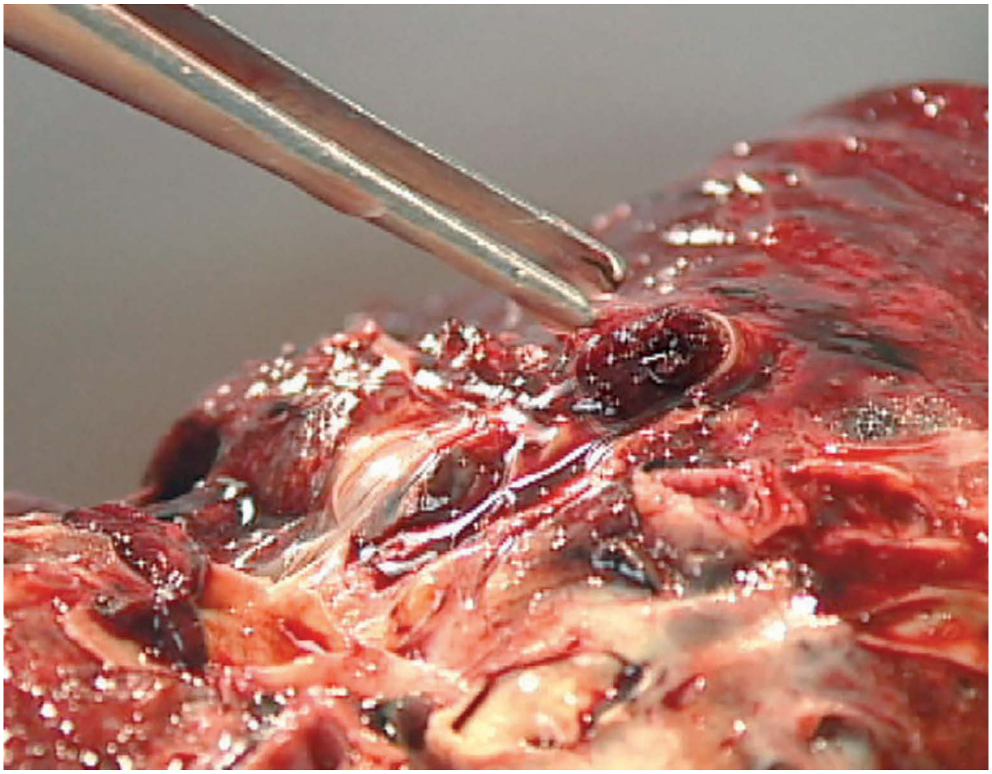


Figure 8.32 Large pulmonary embolus in situ. Dissection of this lung revealed a large thromboembolus (blood clot) in the pulmonary artery branch. These clots usually migrate or embolize from the lower extremities, where, through the venous system, they become wedged in the large pulmonary arteries or the smaller branches, depending on the size. If large enough, these thromboemboli can cause immediate cardiac standstill and sudden death. Smaller thromboemboli cause chest pain and an infarction of a small segment of lung. Pulmonary embolus is the most common cause of death in the hospitalized patient.

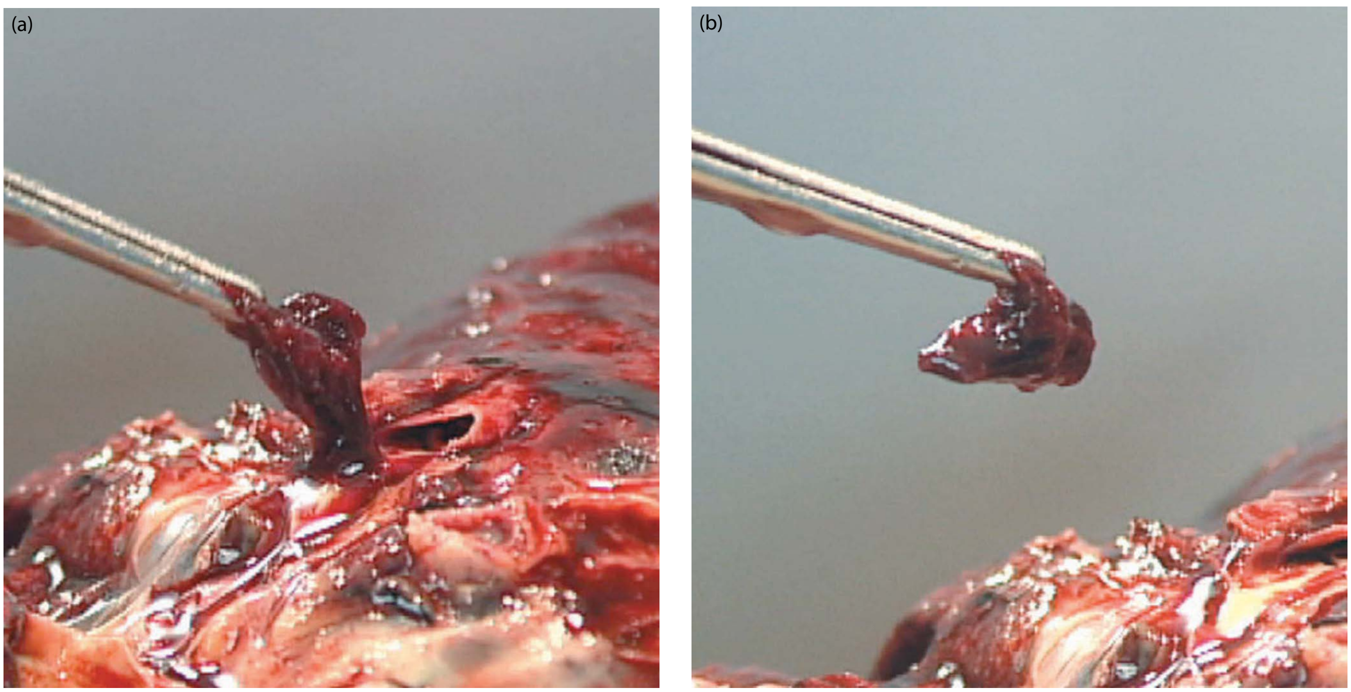


Figure 8.33 (a and b) Large thromboembolus removed. If thromboemboli are gently tugged on, their true morphology can be determined. As this clot is removed, it is slightly adherent to the vessel wall, forming a cast of the vessel. Thromboemboli must be distinguished from postmortem clots, which are common throughout the vascular system after death.

Figure 8.34 Pulmonary infarction. This lung shows a broad, dark-purple area of infarction (top and middle of the figure), which stands out from the pink parenchyma of the overall lung. Pulmonary infarction is the result of a clot large enough to cause tissue necrosis of the lung.

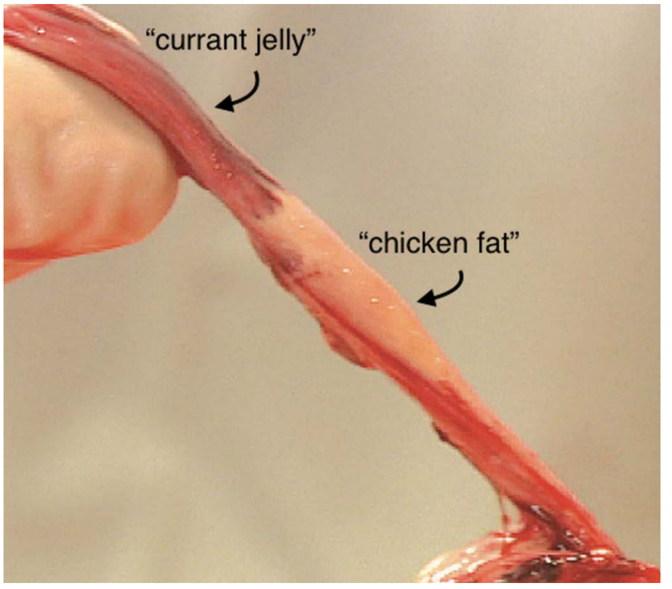


Figure 8.35 Postmortem blood clot. This stringy postmortem clot is being pulled out of a blood vessel. It does not form a cast of the vessel like premortem clots do. Postmortem blood clots are a mixture of two separate areas: a purple, soft, "currant jelly" area and a yellow, harder, "chicken fat" area. It is important for the pathologist to recognize the difference between a premortem thromboembolus and a postmortem blood clot. These two clots can look very similar. If the postmortem clot is mistaken for a premortem clot, the cause of death could be determined erroneously as pulmonary thromboembolus.

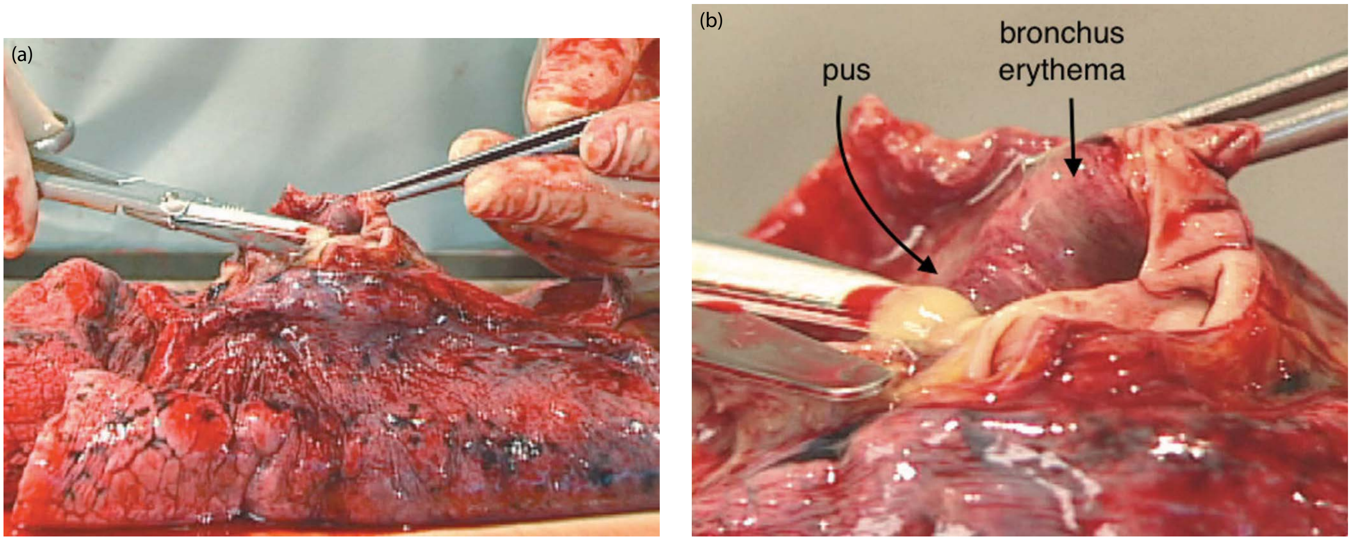


Figure 8.36 Bronchial inflammation. (a) Upon dissecting this bronchus from the hilum, or center of attachment of the lung, a yellow mucoid substance is noted at the tip of the scissors. **(b)** The bronchus is erythematous (red), and pus can be seen on the scissors. These findings suggest bronchitis or bronchopneumonia.

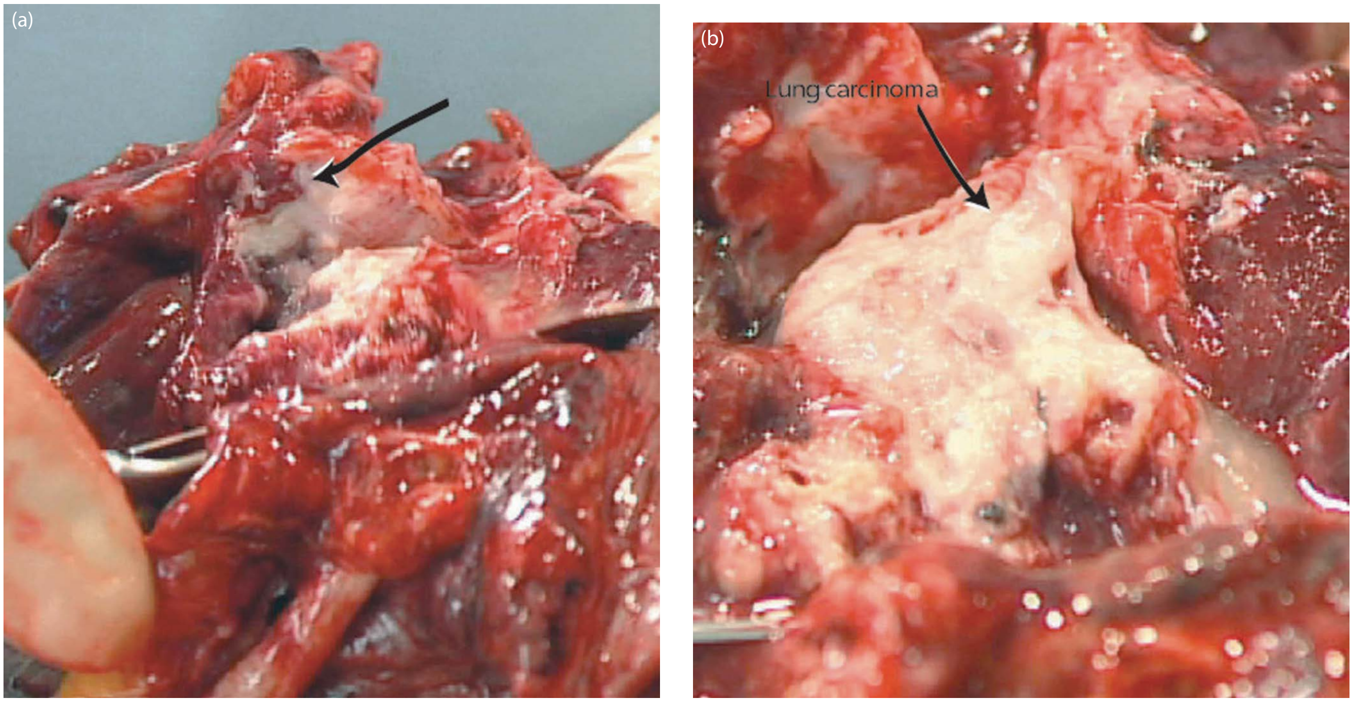


Figure 8.37 (a and b) Carcinoma in the lung hilum. Bronchial dissection at the hilum reveals a whitish tumor, as displayed by the arrows. Cancers grow quickly and tend to outgrow their blood supplies, causing tissue death, or necrosis. This tumor will be sectioned for microscopic examination in order to determine the type of tumor or cancer.

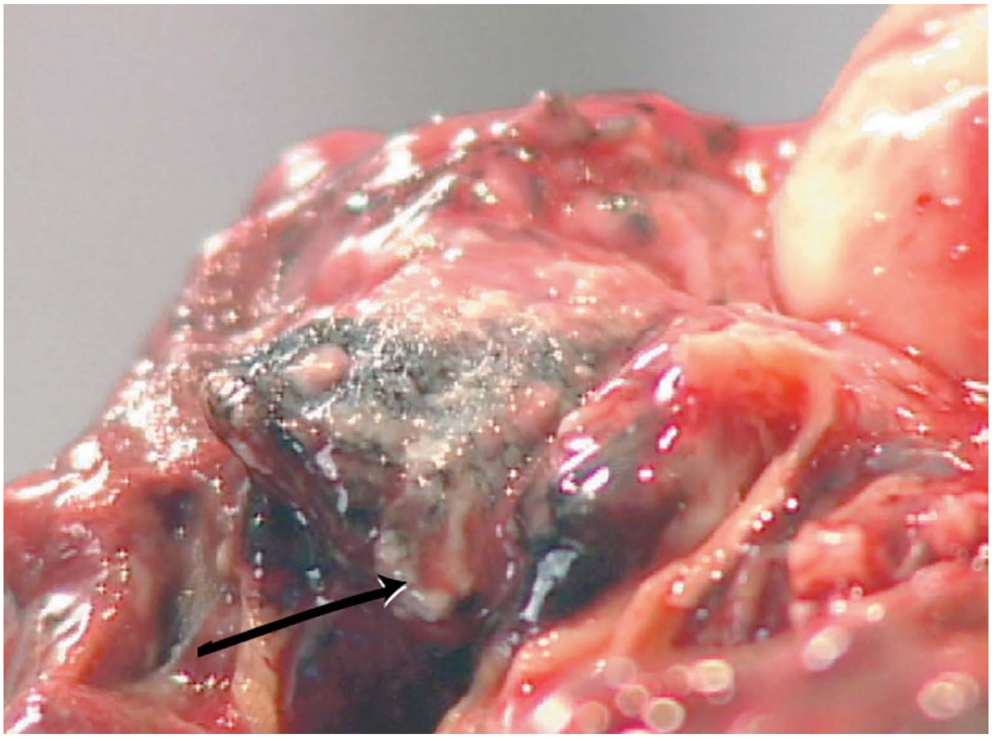


Figure 8.38 Cancer in an anthracotic lymph node. The tumor displayed has metastasized (spread) to the hilar lymph nodes, which are abundant in the hilum of the lung. Anthracosis (black pigment, likely from smoking in this case) is also seen in the lymph node. This tumor, after microscopic review, was determined to be a squamous cell carcinoma, which is found almost exclusively in smokers.

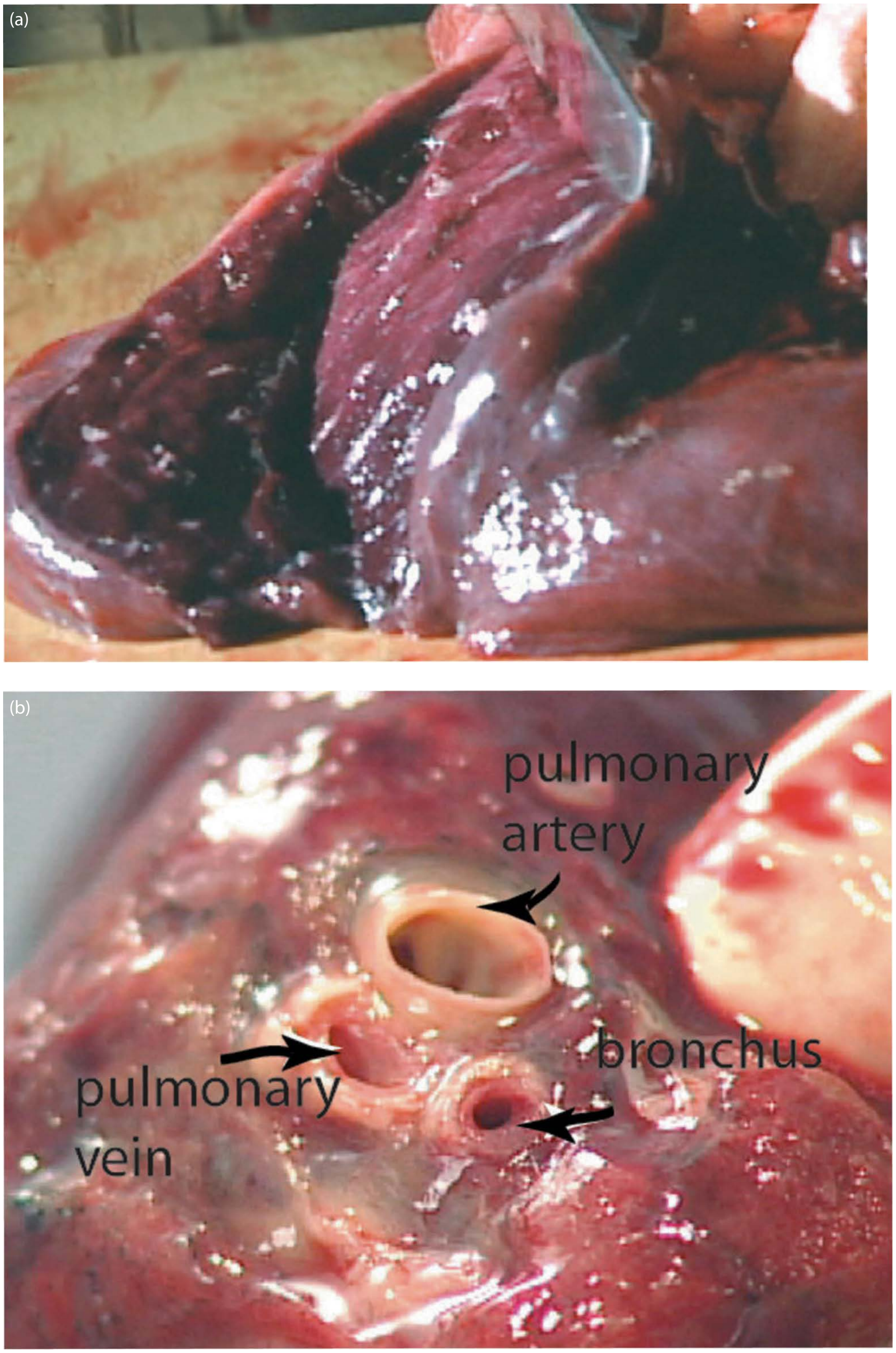


Figure 8.39 Sectioning of the lung. (a) The lung is serially sectioned, revealing the lung parenchyma. **(b)** This image shows a normal pulmonary artery vein and a bronchus.

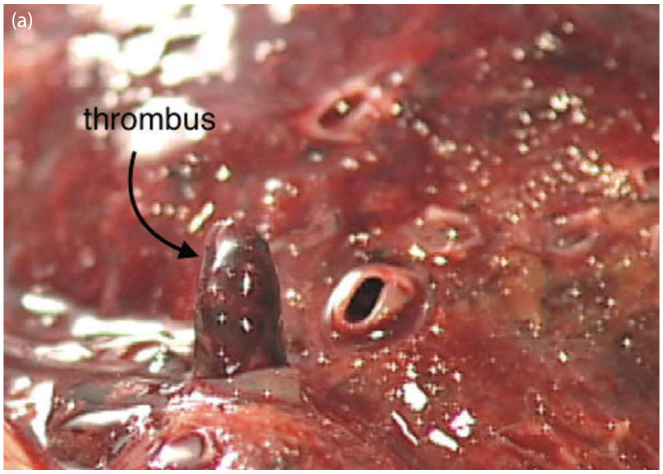


Figure 8.40 Small pulmonary emboli. (a) Further sectioning of this lung shows pulmonary emboli in the smaller pulmonary vessels. These emboli protrude from the vessel wall when cut, as opposed to postmortem clots, which are stringier. **(b)** This adherent clot from the center of the vessel will be submitted for microscopic examination in order to provide further proof that the clot is premortem.

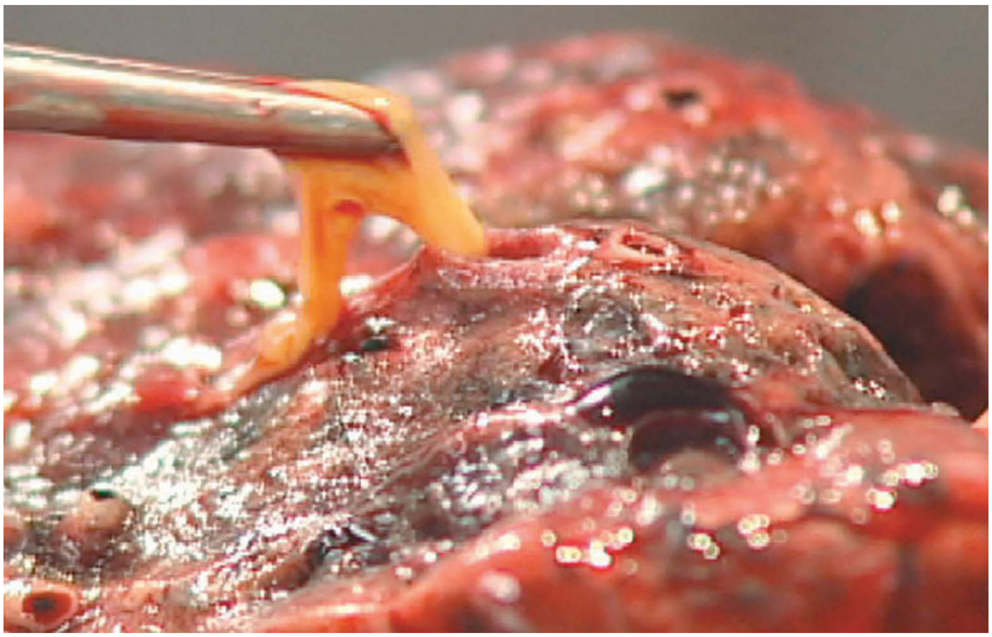


Figure 8.41 Purulent material in the smaller bronchus. Further sectioning of this lung shows yellowish, mucoid pus in the bronchi, indicating bronchopneumonia.

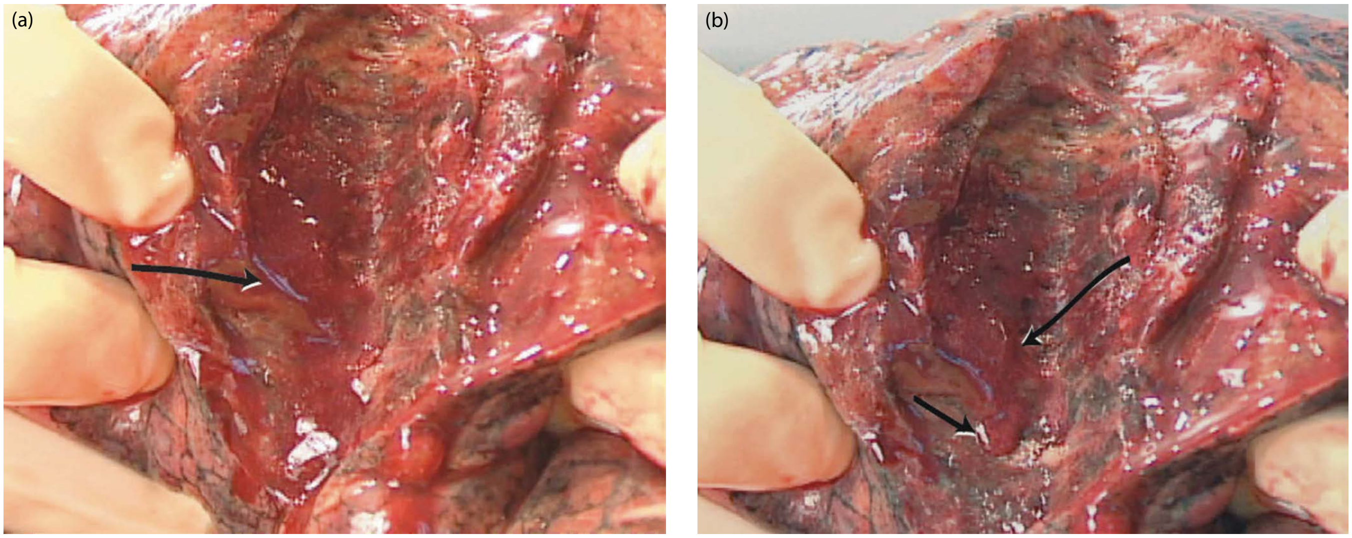


Figure 8.42 (a and b) Pulmonary congestion. Fluid freely flows or cascades from the cut section of lung, indicating congestion (arrows). The congested lung weighs up to twice the normal average weight of approximately 400 g. The normal lung is soft and puffy, still containing air even at autopsy. This lung has a boggy, full feeling. The capillaries, large blood vessels, and tissues are filled with fluid. Lung congestion is a nonspecific finding and generally results from a slow stoppage of the heart.

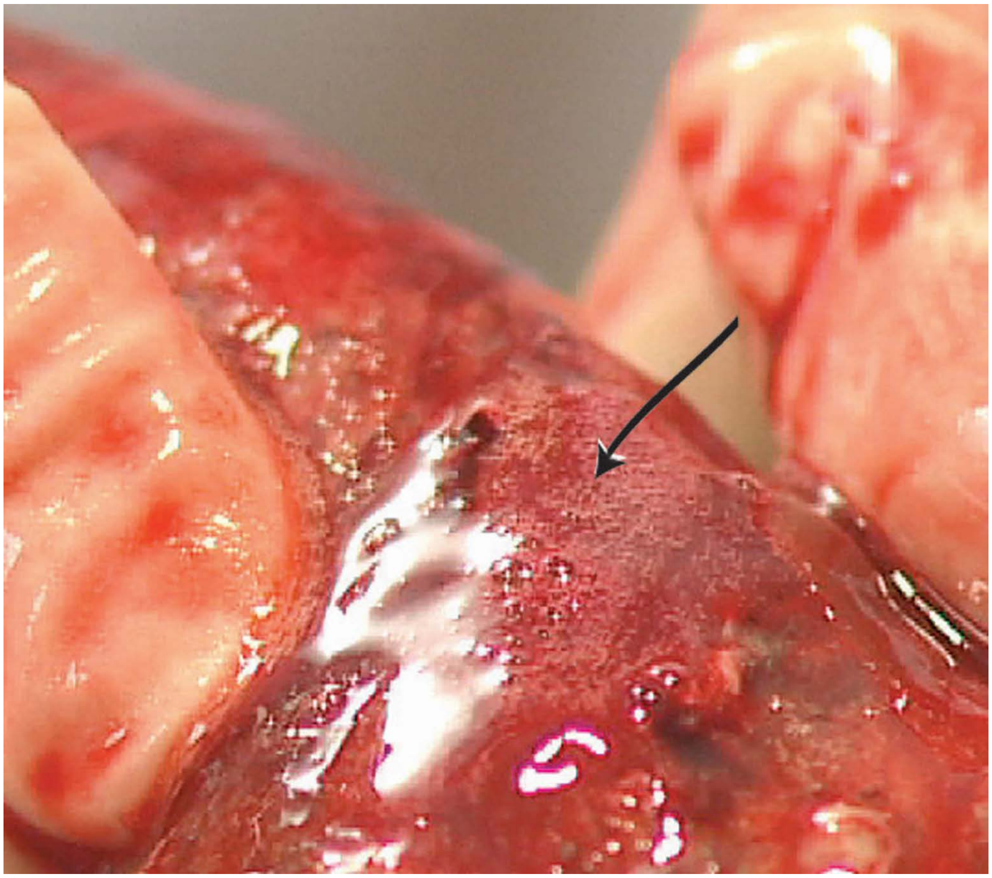


Figure 8.43 Pulmonary edema fluid. This lung section shows edema fluid characterized by fluid exuding from the air-filled spaces, producing bubbles (arrows). Common causes of pulmonary edema include heart failure, drug overdose, and central nervous system pathology. Fluid engorges the vascular system and exudes into the air spaces, where it mixes with air to form a foamy, bloody fluid (see Figure 10.7 for a microscopic view).

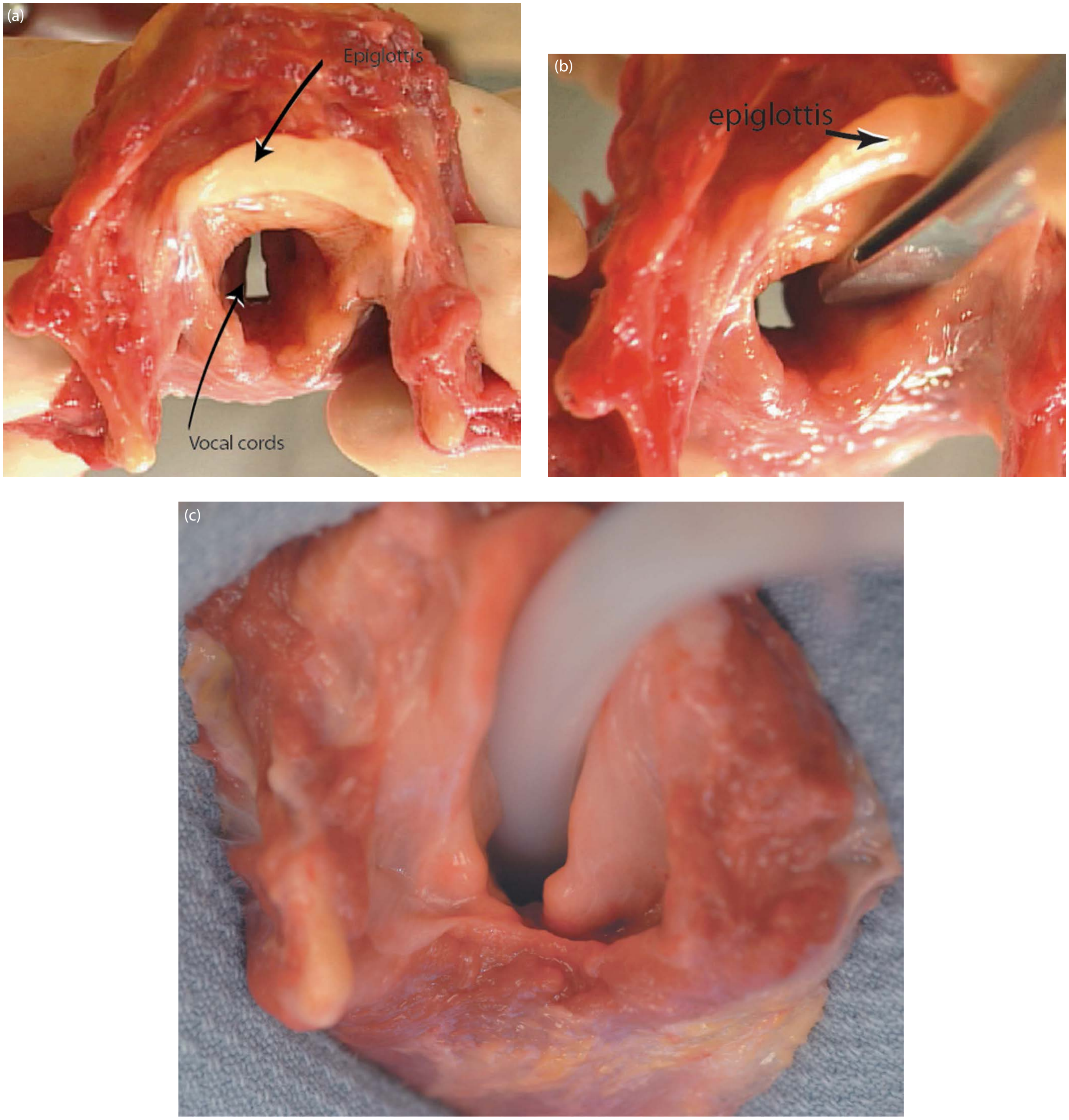
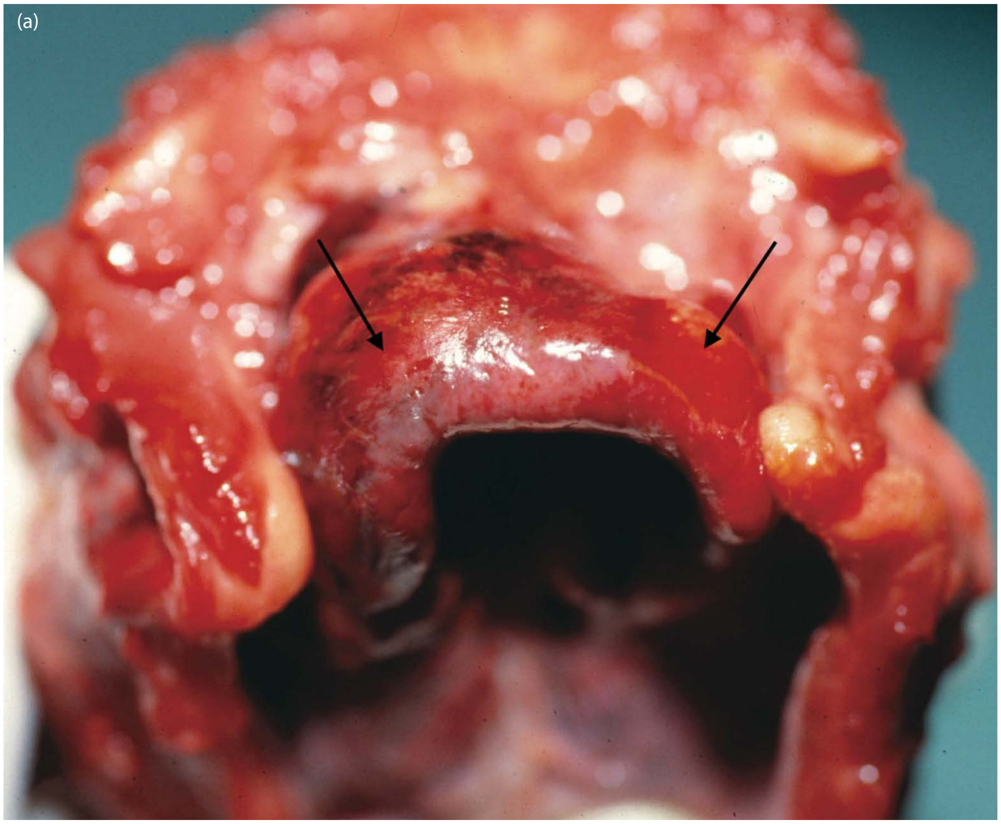


Figure 8.44 The epiglottis and vocal cords as seen during intubation. (a) Note the triangular opening in the middle of the pictures. The vocal cords border this opening. **(b)** The forceps trace the path where the endotracheal tube is placed during intubation. The epiglottis is pushed slightly upward out of the way as the device is inserted between the vocal cords. **(c)** This image shows the relationship of the trachea and the endotracheal tube.



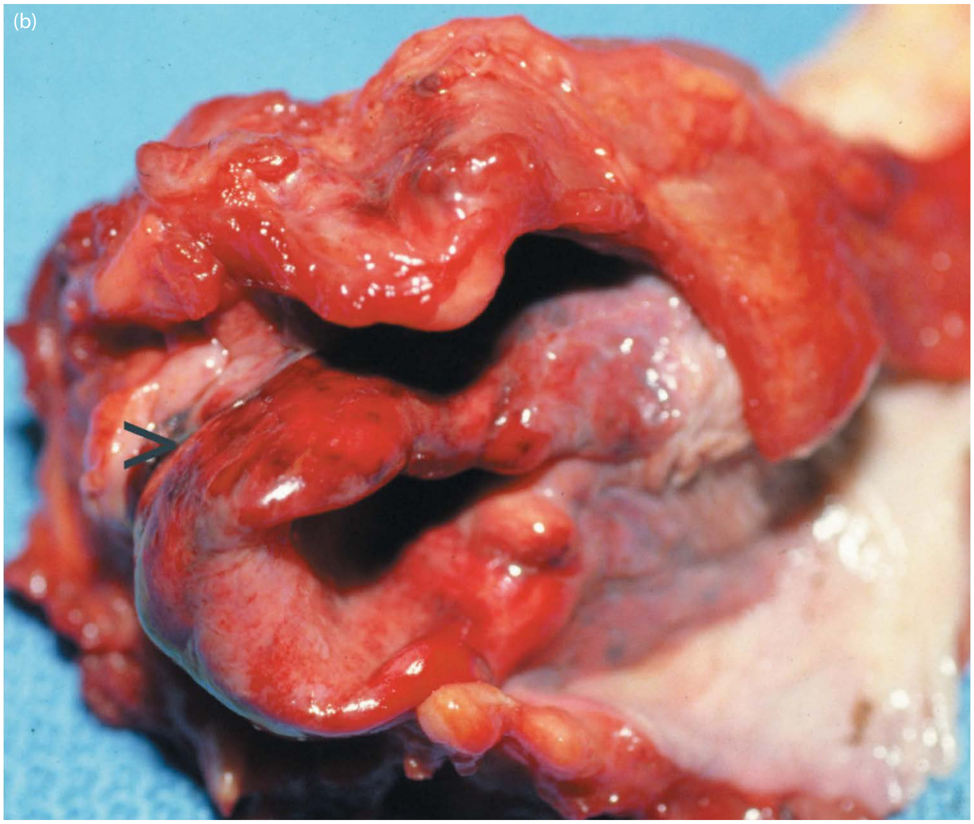


Figure 8.45 (a and b) Epiglottitis. Edema and swelling of the epiglottis can cause occlusion of the airway and death. The rounded, meaty-red, swollen epiglottis shown here was the result of group B S*treptococcus* infection. The victim had trouble breathing and died suddenly after having a severe sore throat for several days.

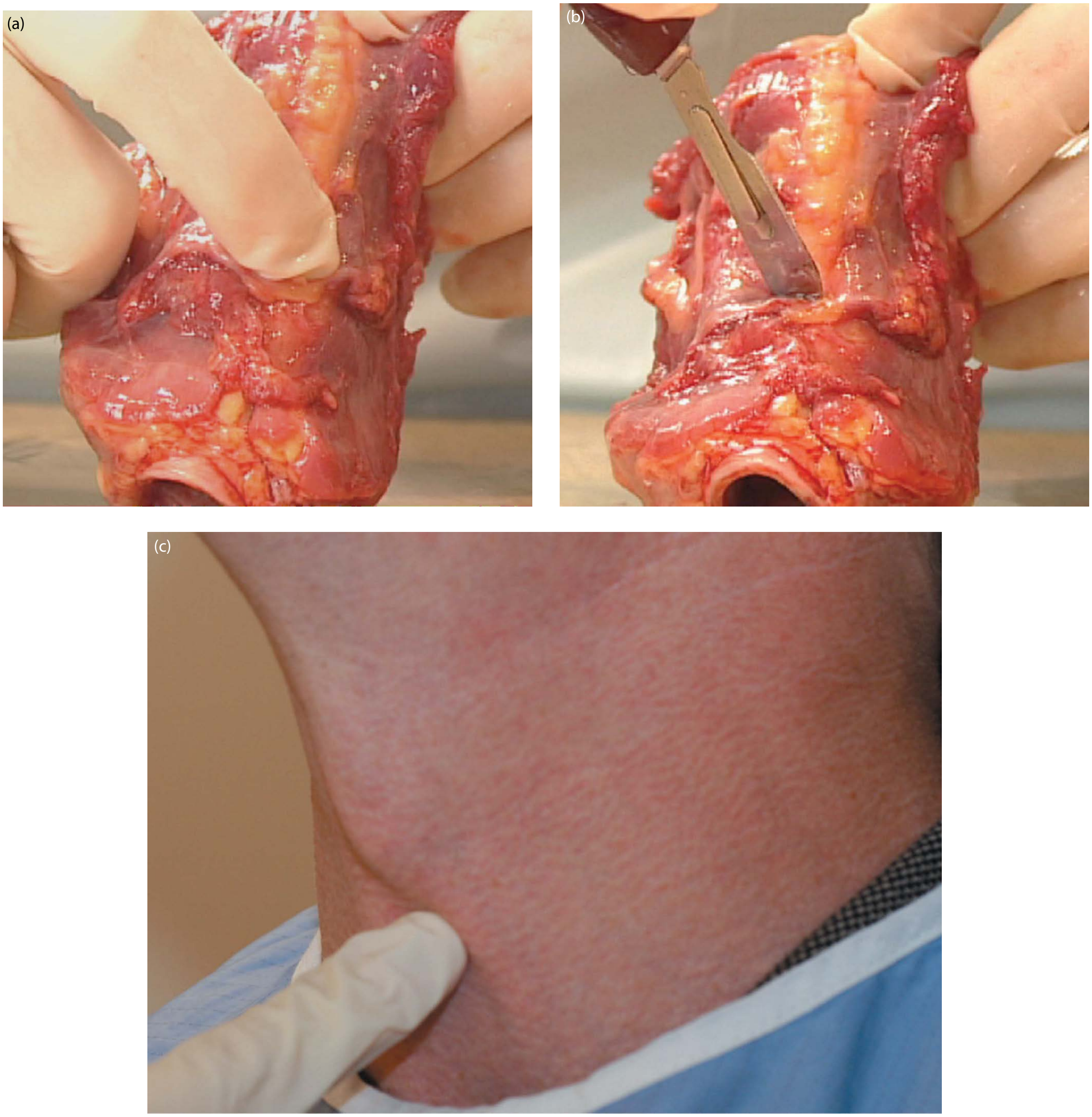


Figure 8.46 (a and b) Cricothyroid membrane. (c) Cricothyroidotomy location. (a and b) To perform a cricothyroidotomy, the cricothyroid membrane, just below the thyroid cartilage, is palpated. **(c)** One can feel this membrane as a break or cleft a little less than a finger's breadth below the "Adam's apple." Emergency cricothyroidotomies are done by physicians or trained emergency medical personnel when an airway cannot be established, such as with severe, traumatic facial injuries.

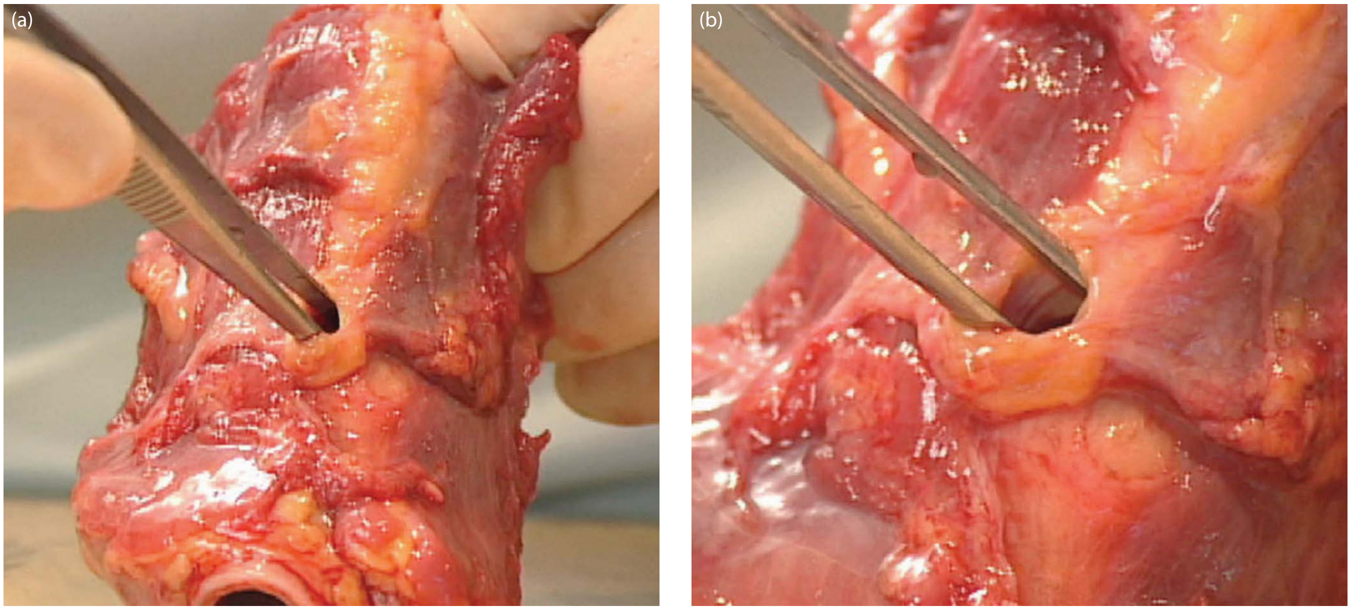


Figure 8.47 (a and b) Opening the cricothyroidotomy. The opening is made and then must be kept open for ventilation of the patient.

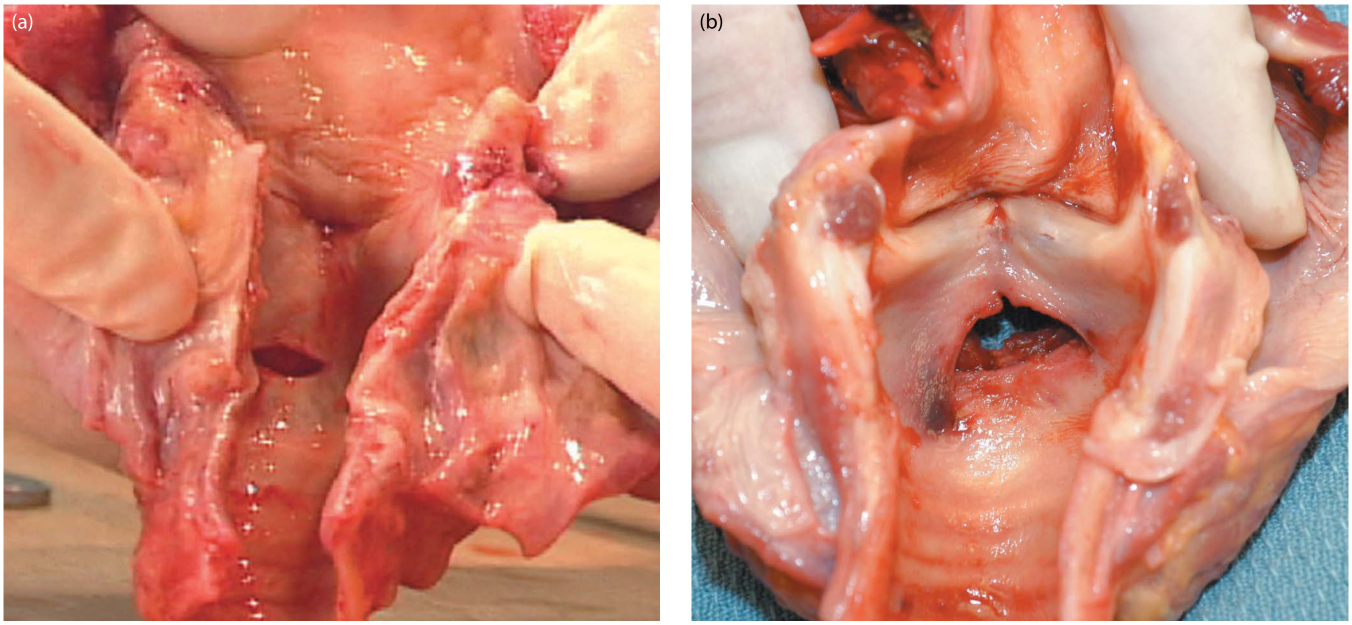


Figure 8.48 (a) Internal cricothyroidotomy site. The site of the cricothyroidotomy is seen well below the vocal cords. **(b) Proper cricothyroidotomy.** This image shows an actual cricothyroidotomy performed properly in the field. The cut is below the vocal cords.

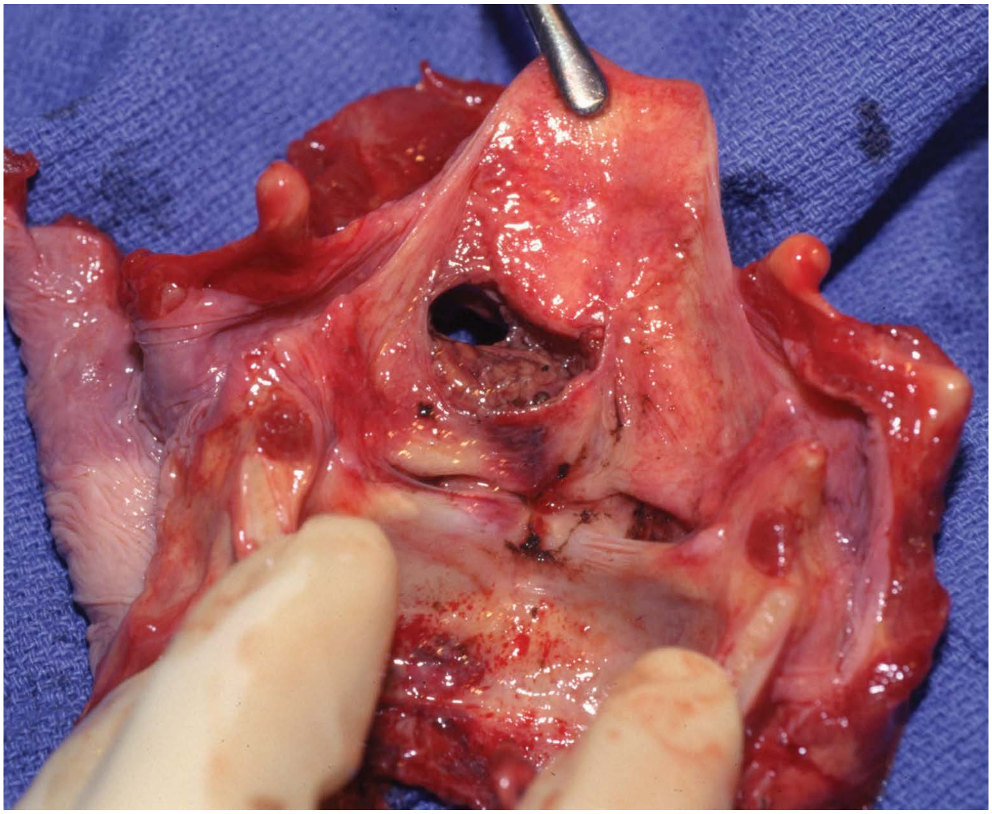


Figure 8.49 Improper cricothyroidotomy. This attempted cricothyroidotomy, performed in the field, was placed above the vocal cord erroneously. Vocal cord damage might have resulted if the patient had survived.

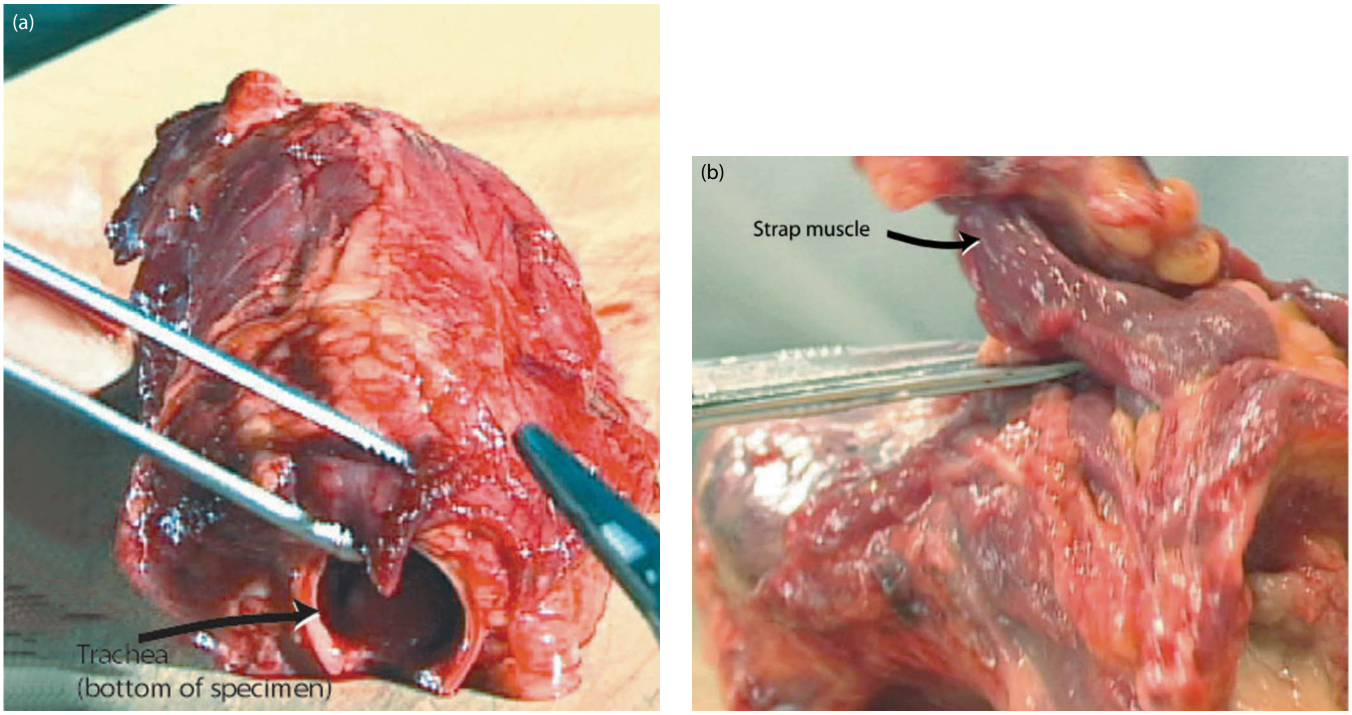
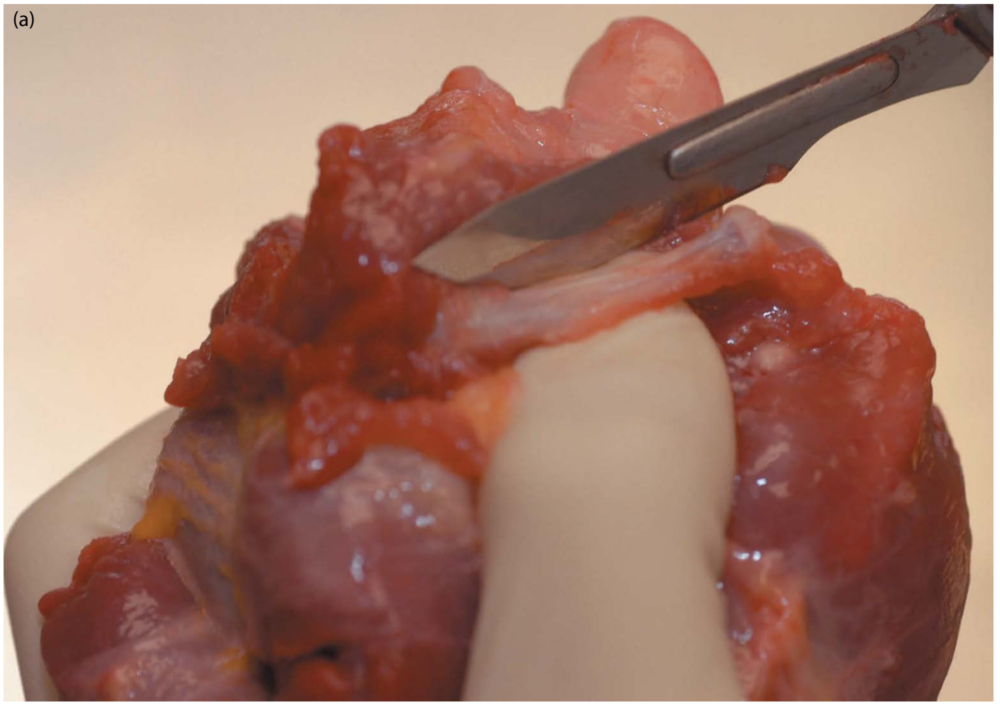


Figure 8.50 (a and b) Strap muscle dissection. The strap muscles are in the anterior midline of the removed neck organs and are dissected away. During dissection, the pathologist is looking for hemorrhage.



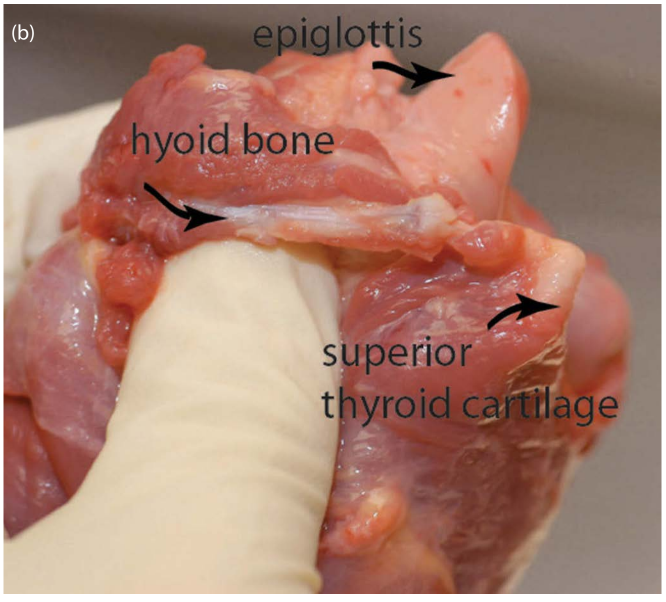


Figure 8.51 Examination of the hyoid bone for injury. (a) The hyoid bone is "cut down on," exposing the periosteum. Fractures of the hyoid bone or hemorrhage of soft tissue around the hyoid bone can be seen in strangulation. **(b)** The superior thyroid cartilage extends upward from the thyroid cartilage and can also show surrounding hemorrhage or fracture in strangulation.

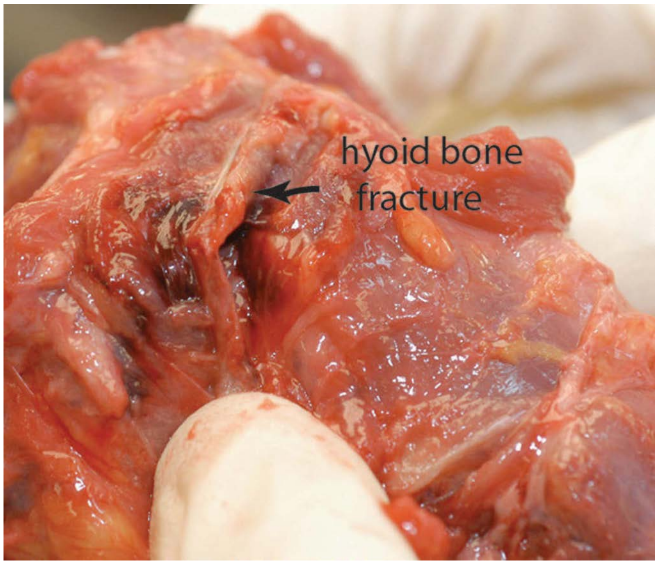


Figure 8.52 Hyoid bone fracture in strangulation. The hyoid bone is fractured, and hemorrhage surrounds this fracture.

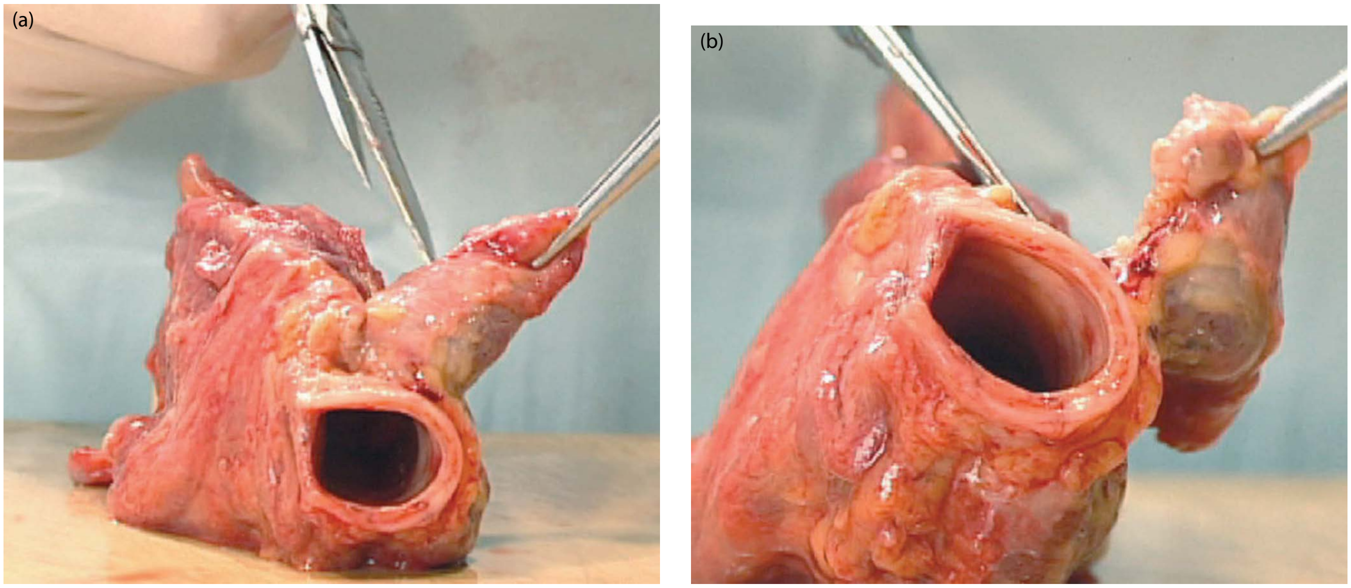


Figure 8.53 (a and b) Dissecting away the thyroid. The thyroid gland is dissected away from the neck to look for hemorrhage or tumors.

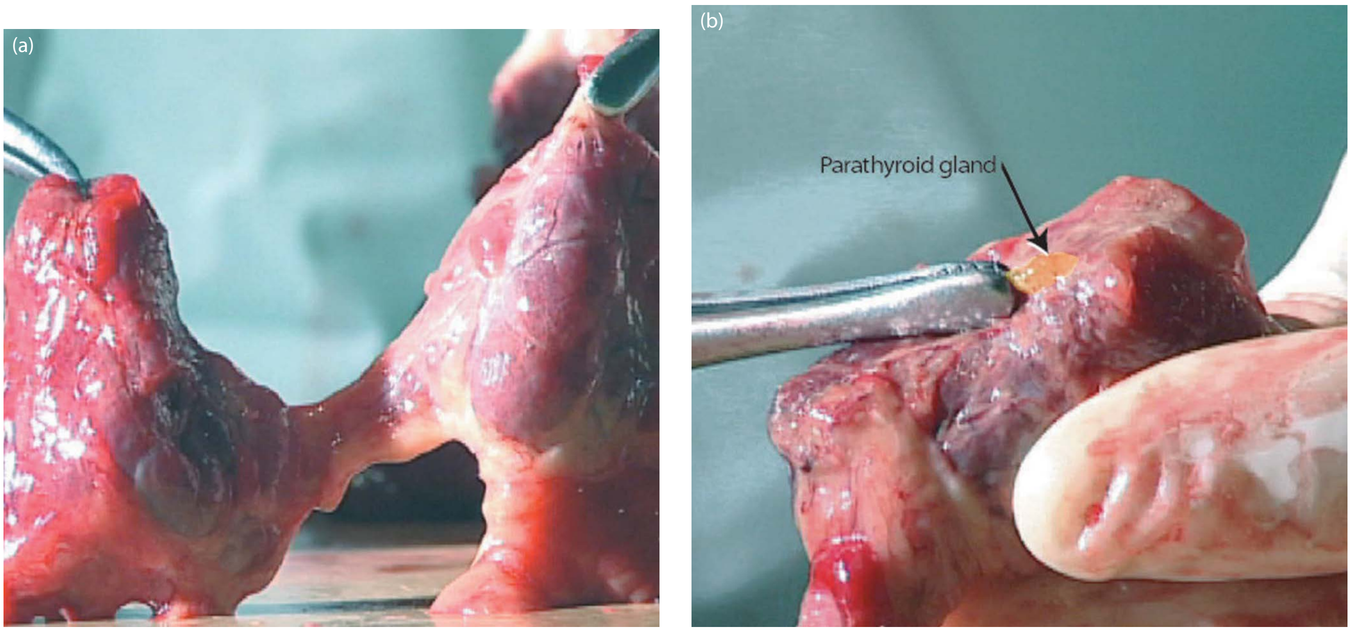


Figure 8.54 Examination of the thyroid and parathyroid glands. (a) The thyroid is held up to reveal two lobes and the connecting isthmus. **(b)** The small, round, yellow parathyroid gland can be seen just to the right of the forceps tip. The parathyroid gland mainly controls calcium levels in the body via a hormone called calcitonin.

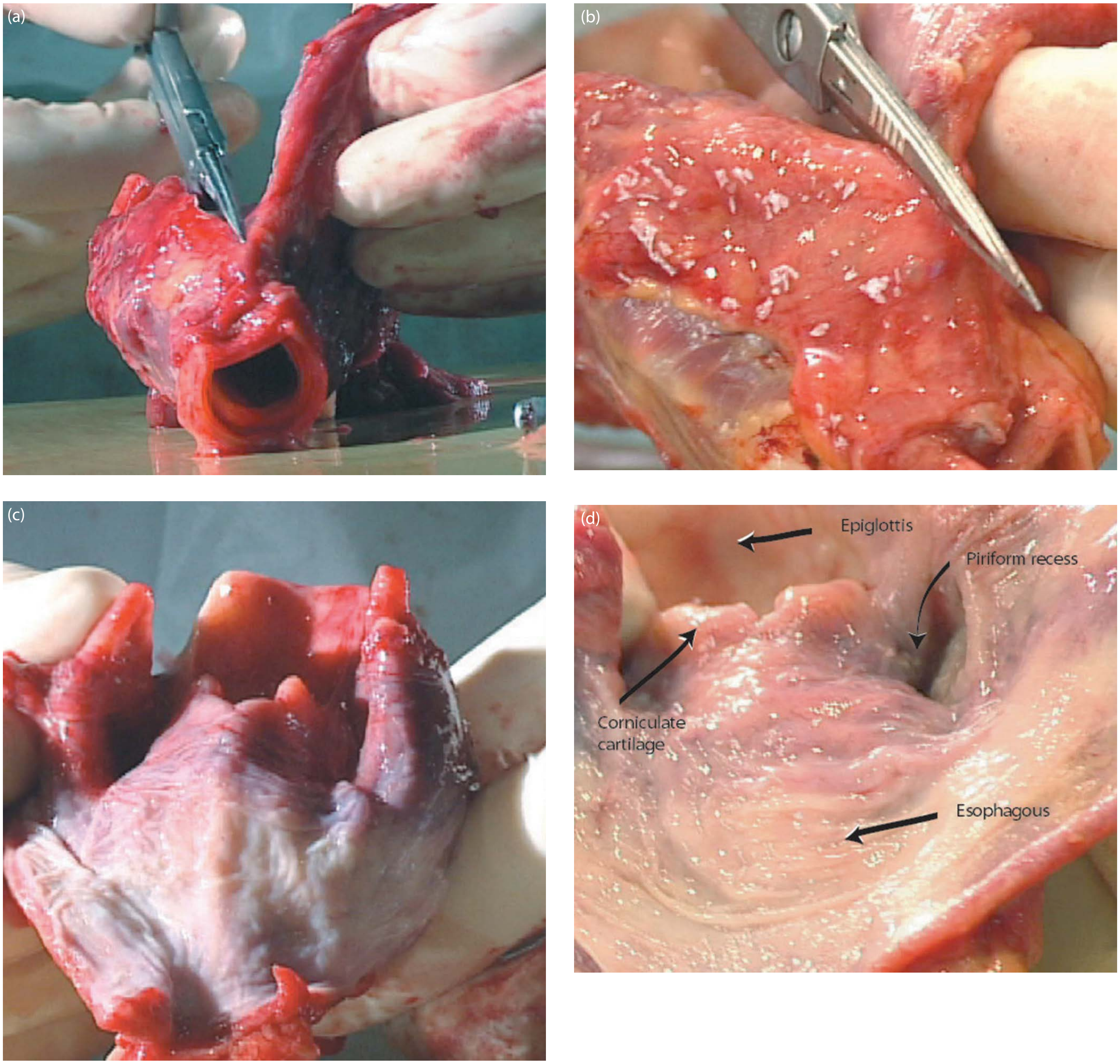


Figure 8.55 (a–d) Opening the esophagus. The neck specimen is turned around and the proximal portion of the esophagus is opened to reveal the smooth, white–pink mucosa. Foreign bodies can lodge at the origin of the esophagus and close off the trachea, resulting in asphyxia.

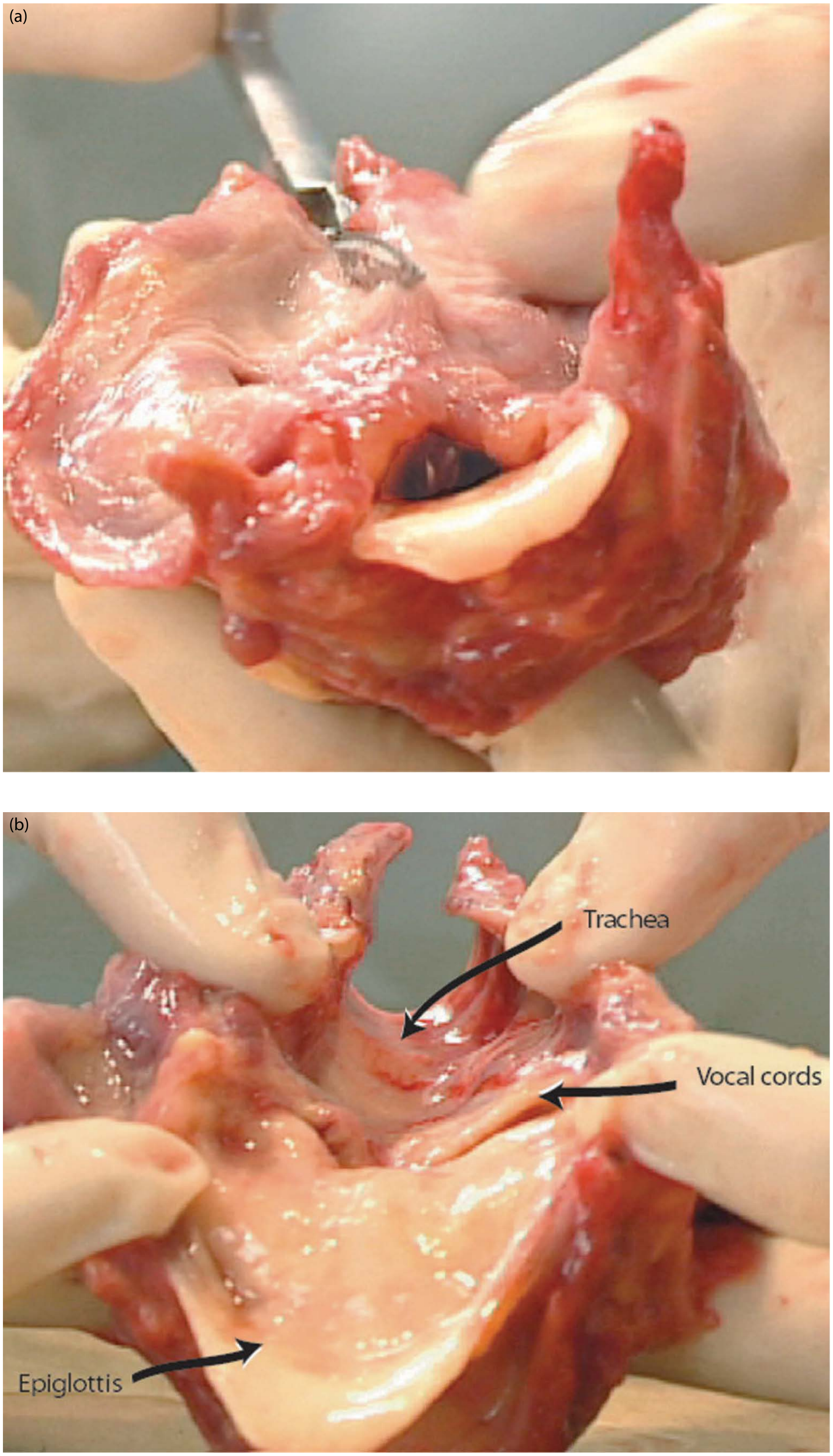
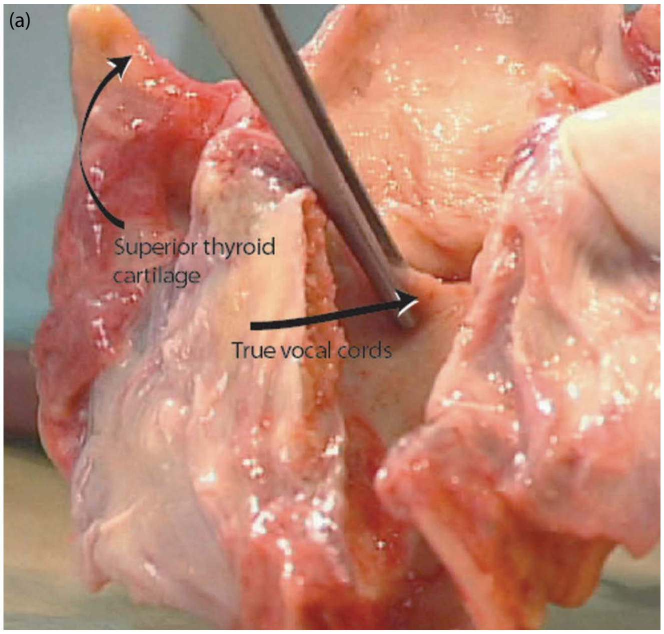
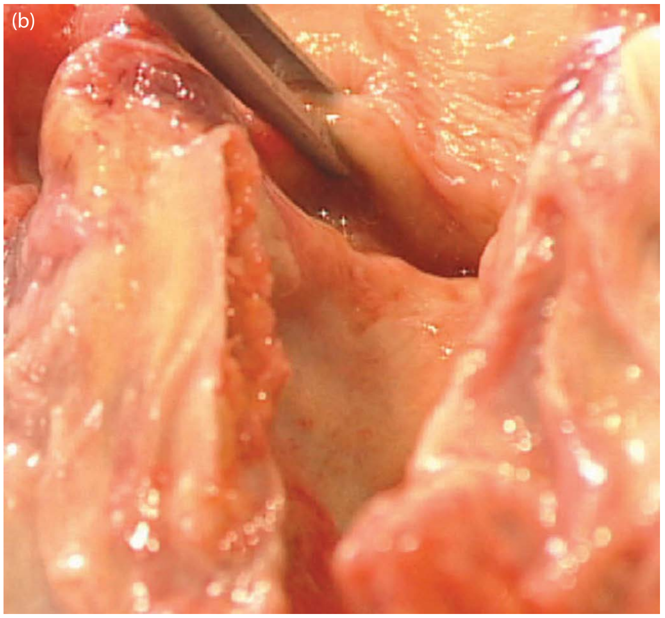


Figure 8.56 Opening the trachea. (a) The trachea is opened from the posterior aspect (back), where the anterior–lateral cartilaginous rings give way to soft tissue. **(b)** The trachea is opened to examine the vocal cords and mucosa.





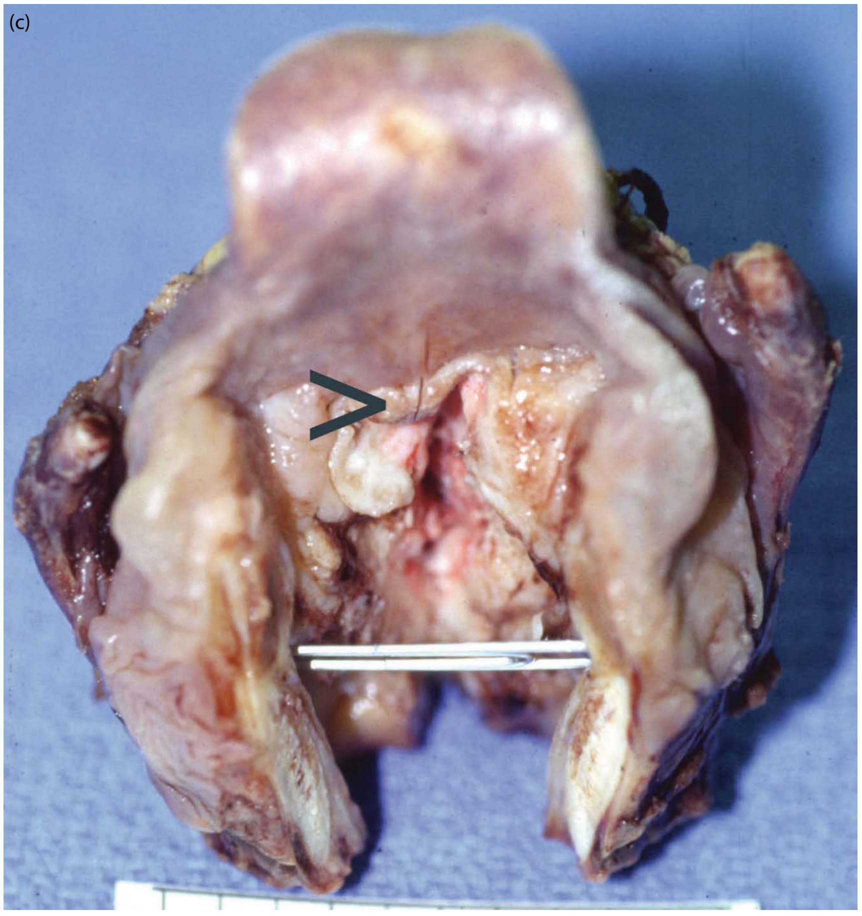


Figure 8.57 (a and b) True and false vocal cords. The forceps are holding the true vocal cords, which are just below the false vocal cords, held by the forceps in the second figure. **(c) Squamous cell carcinoma.** The vocal cords are sites for squamous cell carcinoma (arrow), especially in smokers, and polyps in those who abuse their voices.

Figure 8.58 Normal liver. The liver is much larger than most autopsy neophytes realize. The liver depicted is approximately 25 cm (over 10 inches) wide. The average liver weighs approximately 1930 g (4.25 lb) in a 77-kg (170-lb) man. The liver performs many functions and is essential for life. Important functions of the liver include production of bile, production of blood coagulation proteins, breakdown of drugs and toxins, filtration of blood, and metabolism of fat proteins and carbohydrates.

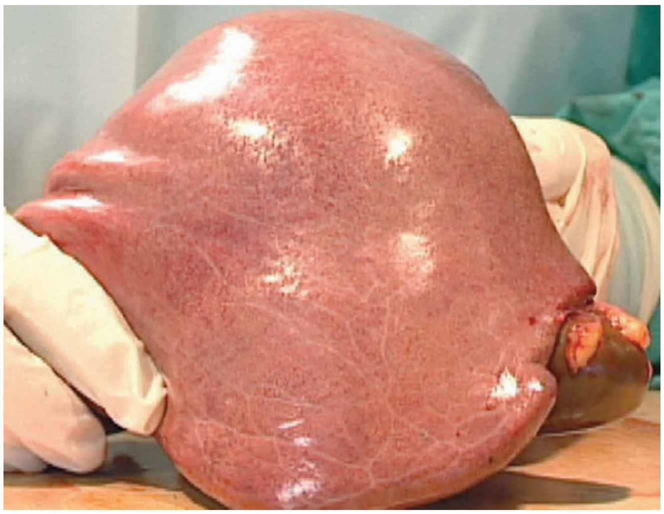


Figure 8.59 Examination of the liver capsule. The capsule of the liver is examined. The liver is dome-shaped, owing to its position in the body just under the right diaphragm. This liver shows chronic passive congestion (see Figure 8.63).

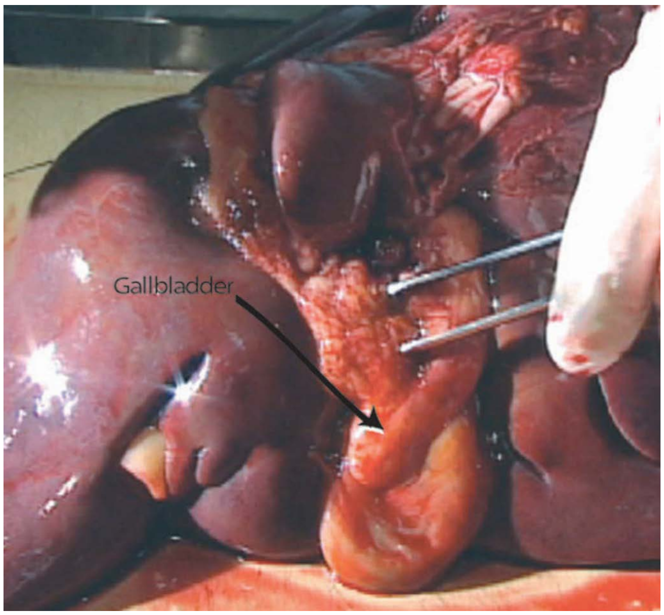


Figure 8.60 Porta hepatis examination. The liver is turned over to reveal the posterior–inferior side. The gallbladder can be seen below the forceps. The forceps is in the region of the porta hepatis, an area containing lymph nodes.

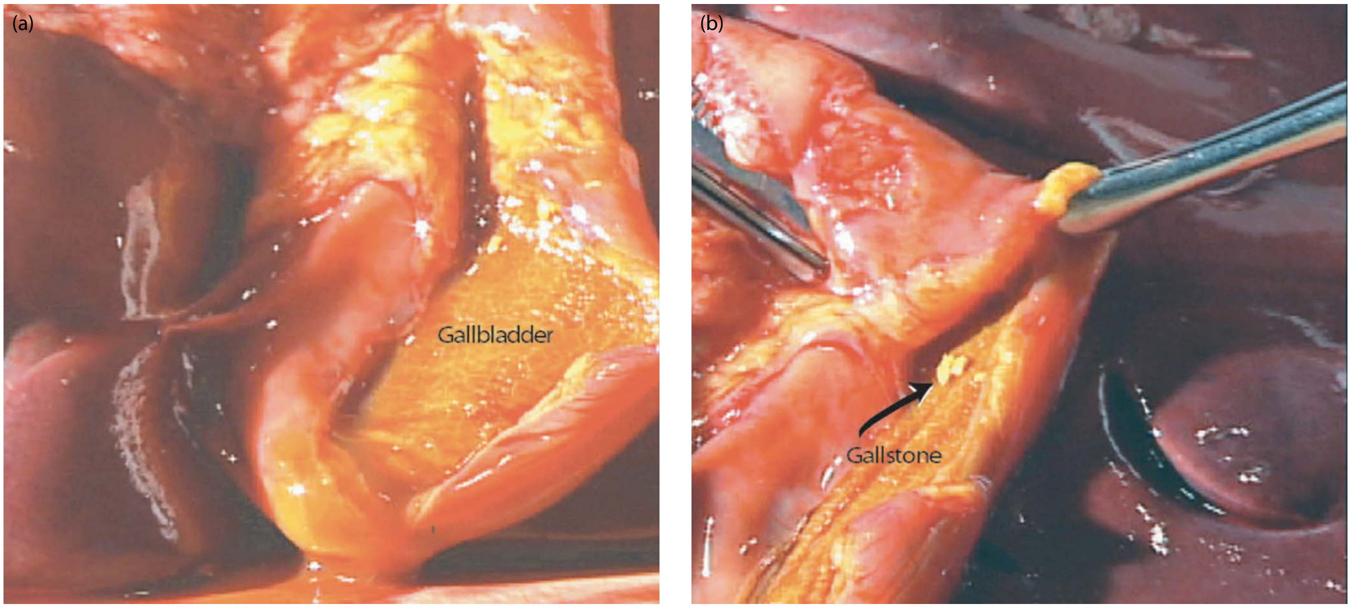


Figure 8.61 (a) Gallbladder. The gallbladder contains bile. **(b) Gallstones.** A closer examination of the opened gallbladder reveals greenish–yellow gallstones.

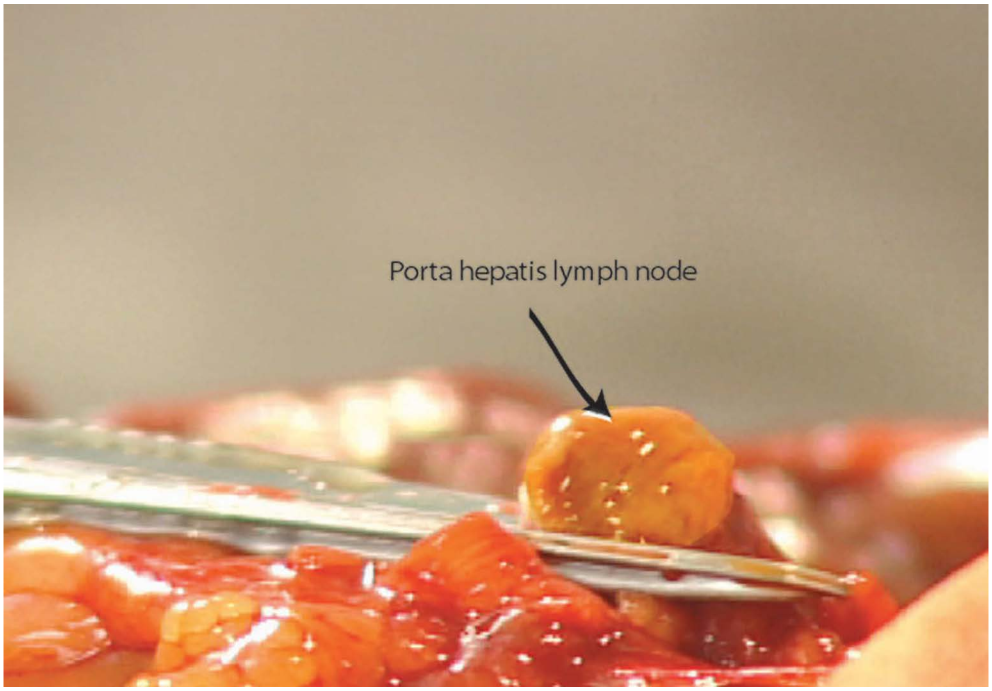
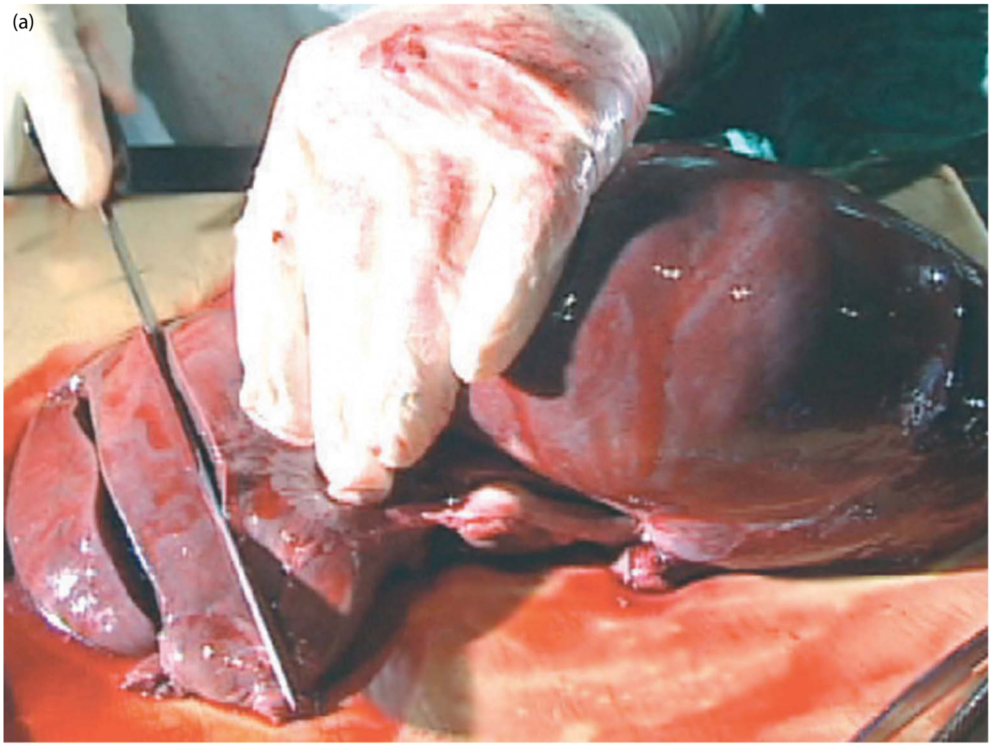


Figure 8.62 Porta hepatis lymph node. Examination of the porta hepatis reveals a large lymph node. These lymph nodes can contain metastatic cancers or granulomas, chronic reactive inflammations in drug addicts who inject drugs into their lower extremities.



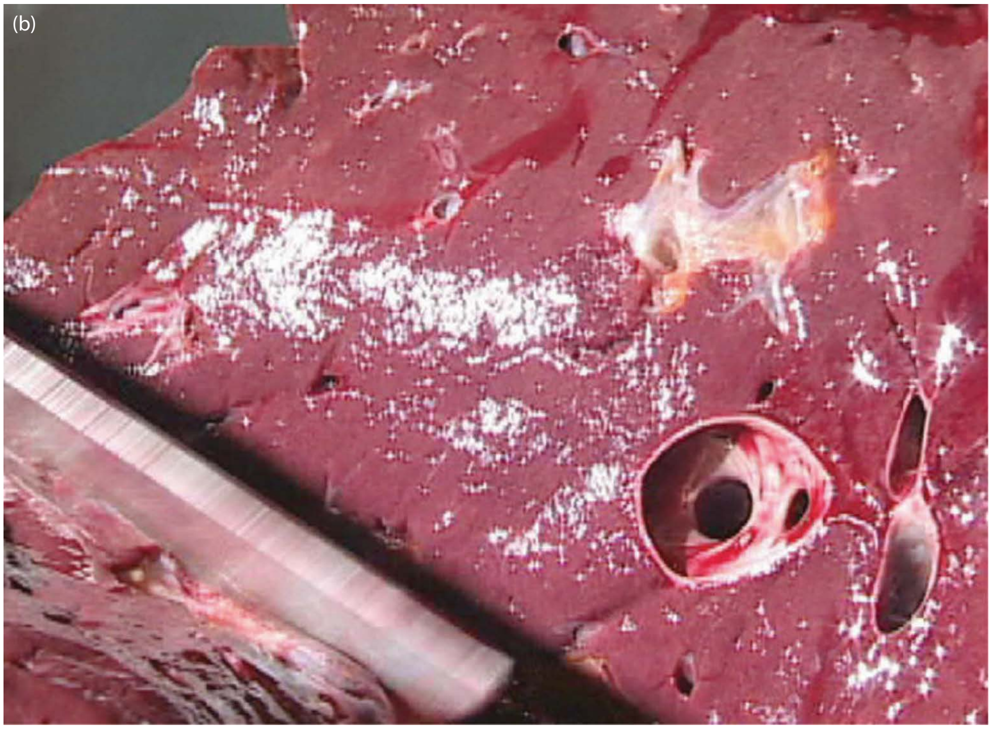


Figure 8.63 Sectioning the liver. (a) The liver is serially sectioned, continuously inspected, and felt for tumors and other abnormalities. **(b)** A cut section shows a normal liver, which is a brown color. The large cavernous veins seen in the right lower part of the image are characteristic of the normal liver.

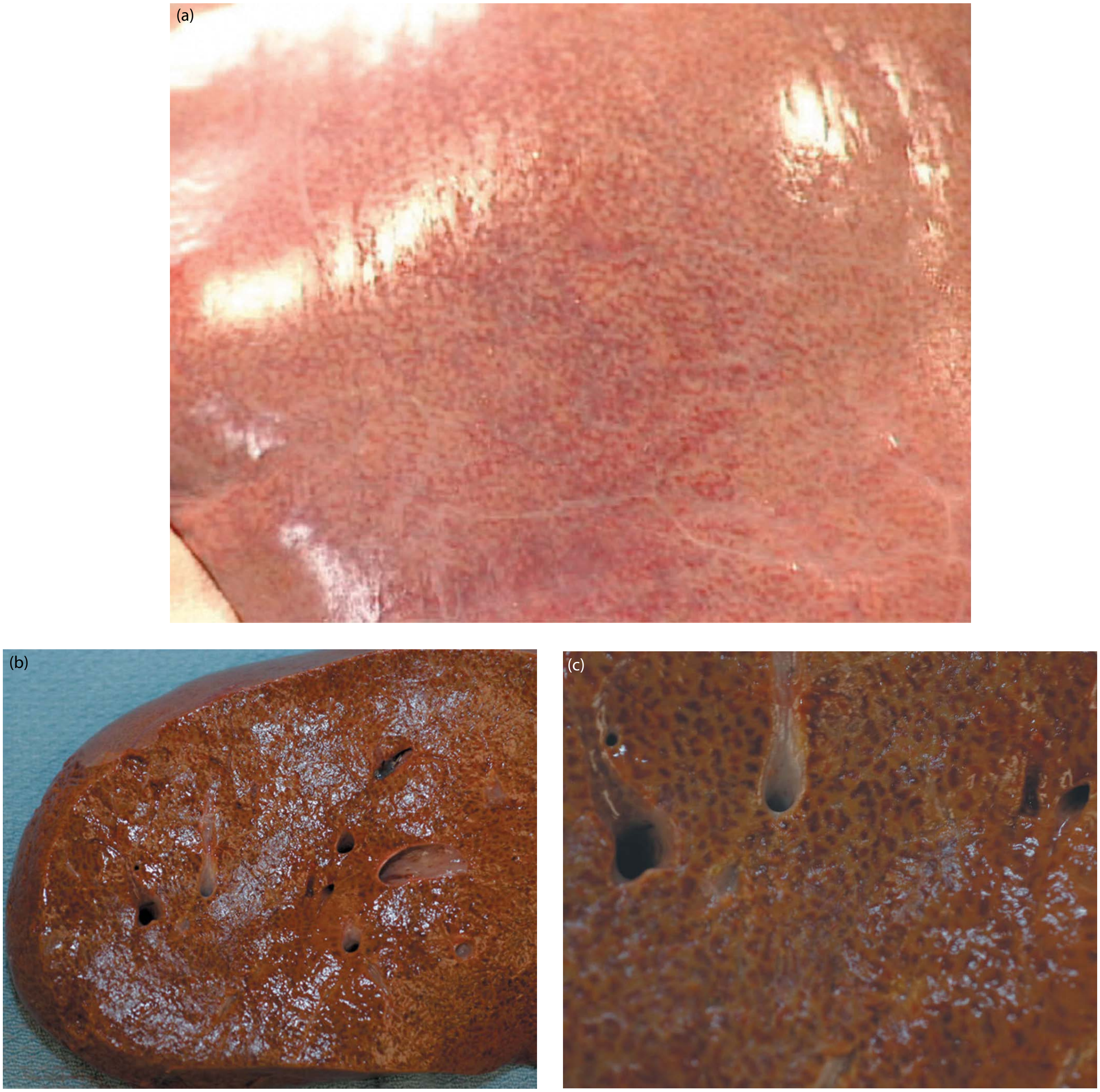


Figure 8.64 (a–c) Chronic passive congestion of the liver. A close-up of the liver shows chronic passive congestion of the liver, characterized by alternating light and dark contrasted areas. This appearance has been called "nutmeg liver," since the cut liver resembles a cut nutmeg. Gross descriptions in pathology occasionally reference food, drinks, and other common objects. The aim of gross descriptions is to communicate observations plainly. The gross appearance reflects the microscopic appearance. The dark areas are largely blood that has pooled around the central vein, or the "draining area" of blood through the liver.

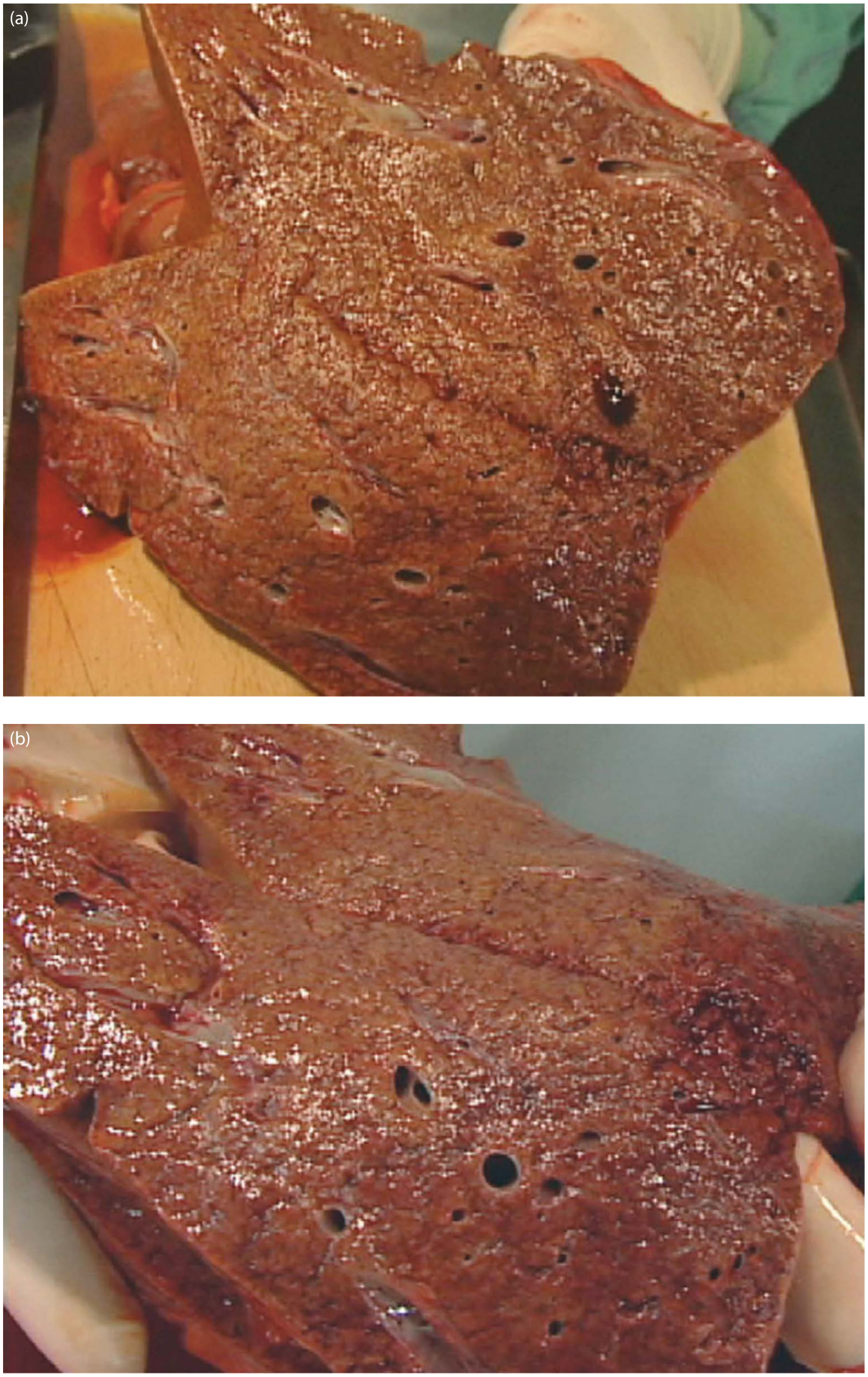


Figure 8.65 (a and b) Cirrhosis of the liver. Cirrhosis is a scarring of the liver. It is the way the liver reacts to an injury. The injury can be from alcohol abuse, an acetaminophen overdose, or chronic ischemia due to heart failure. In cirrhosis, the liver becomes very hard so that blood cannot flow normally through it. This causes the blood to back up elsewhere in the body, such as in the esophagus (causing esophageal varices). In addition, the liver begins to fail due to a lack of cells to perform work, such as making clotting factors. As a result, the patient is prone to spontaneous bleeding. A common problem for the cirrhotic patient is the rupture of dilated veins around the esophagus, and clotting is less likely to occur due to liver cell loss. When advanced, this condition is irreversible and very commonly fatal.

Figure 8.66 Spleen capsule examination. The spleen is the largest collection of lymph tissue in the body. In addition to recycling aged red blood cells, the spleen helps the body fight some infections, such as the encapsulated bacterium *Streptococcus pneumoniae*. The spleen is examined on the outer surface for lacerations or tumors. The capsule of the spleen is very thin and easily torn with trauma. Because a major function of the adult spleen is to recycle red blood cells, the spleen is vascular. Laceration of the spleen can cause extensive internal hemorrhage.

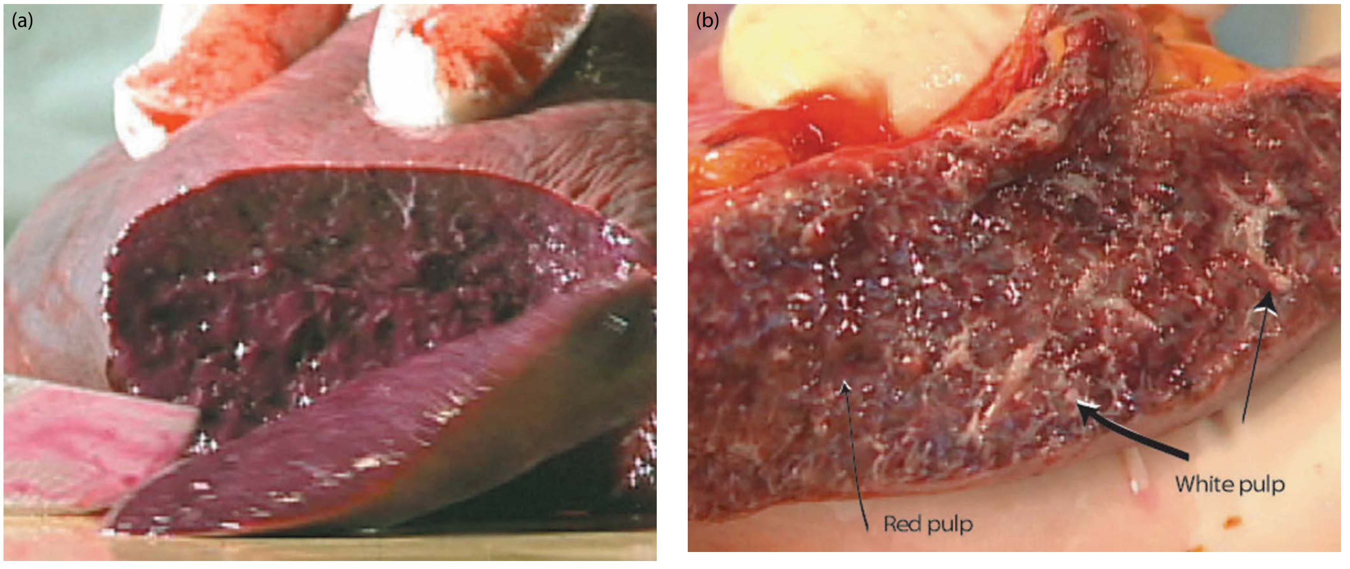
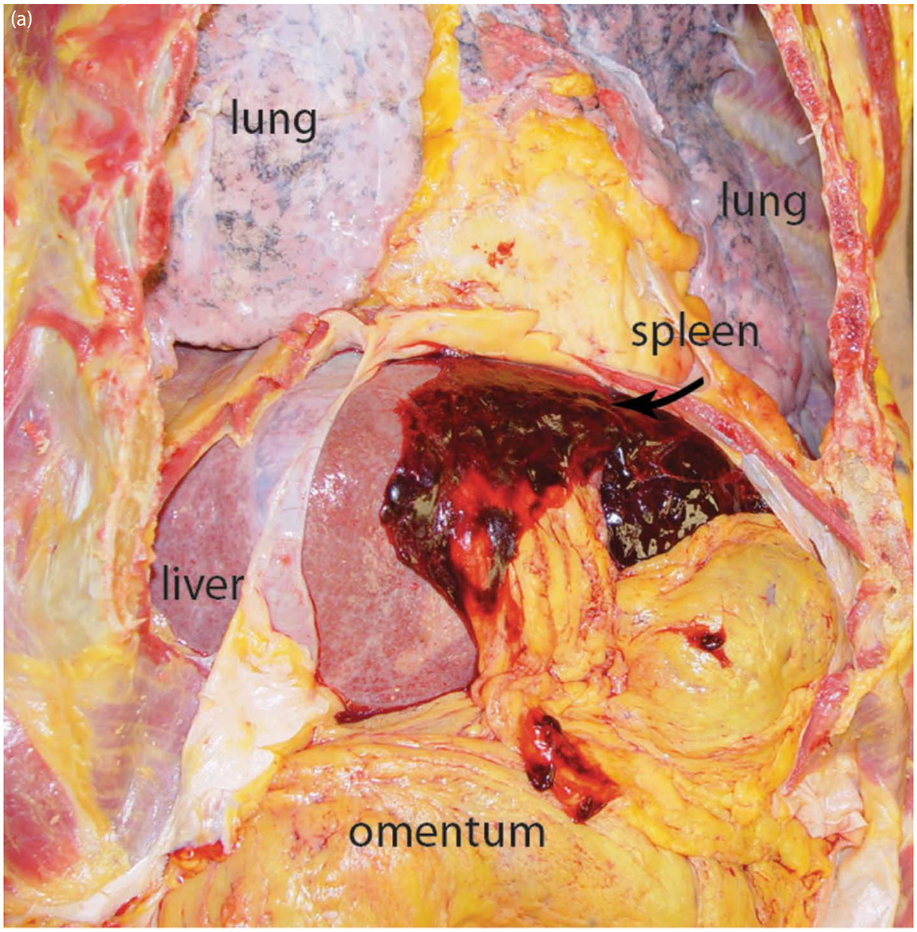


Figure 8.67 (a and b) Spleen sectioning. On sectioning the spleen, one can see the aptly named red pulp. The white dots are the white pulp. Red cells pool in the sinusoids of the red pulp. The capsule of the spleen is very thin, making it susceptible to rupturing easily with trauma.



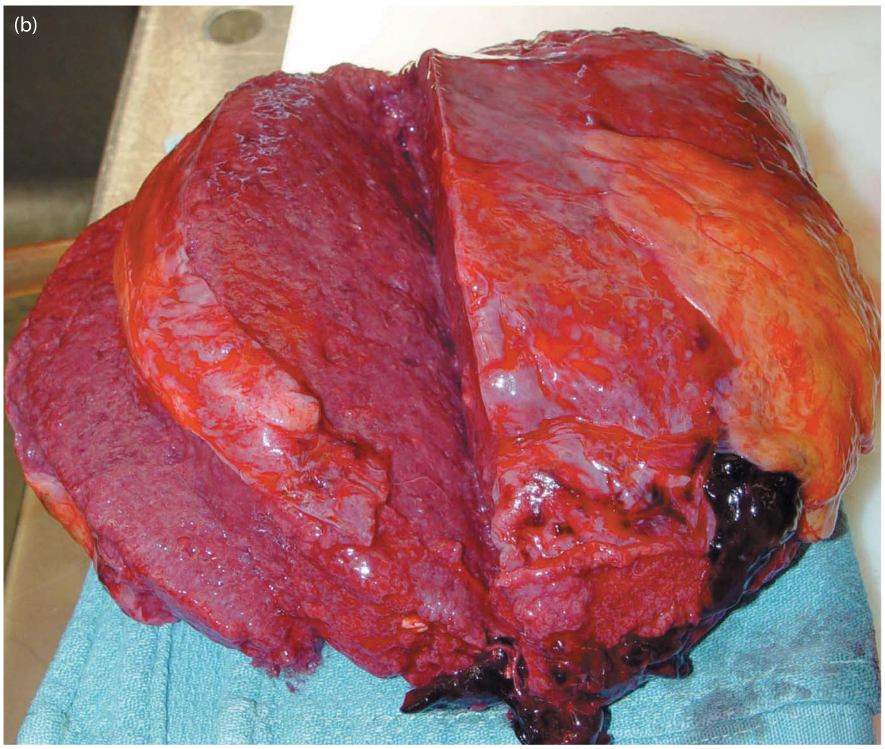


Figure 8.68 Ruptured spleen. (a) A hematoma can be seen in this patient who fell down their steps at home. The source of the hemorrhage is seen in the left upper quadrant of the abdomen. The spleen has a lacerated capsule with an attached hematoma. **(b)** The spleen is enlarged (over 600 g; normal is approximately 120 g), making it more susceptible to traumatic or even spontaneous rupture.

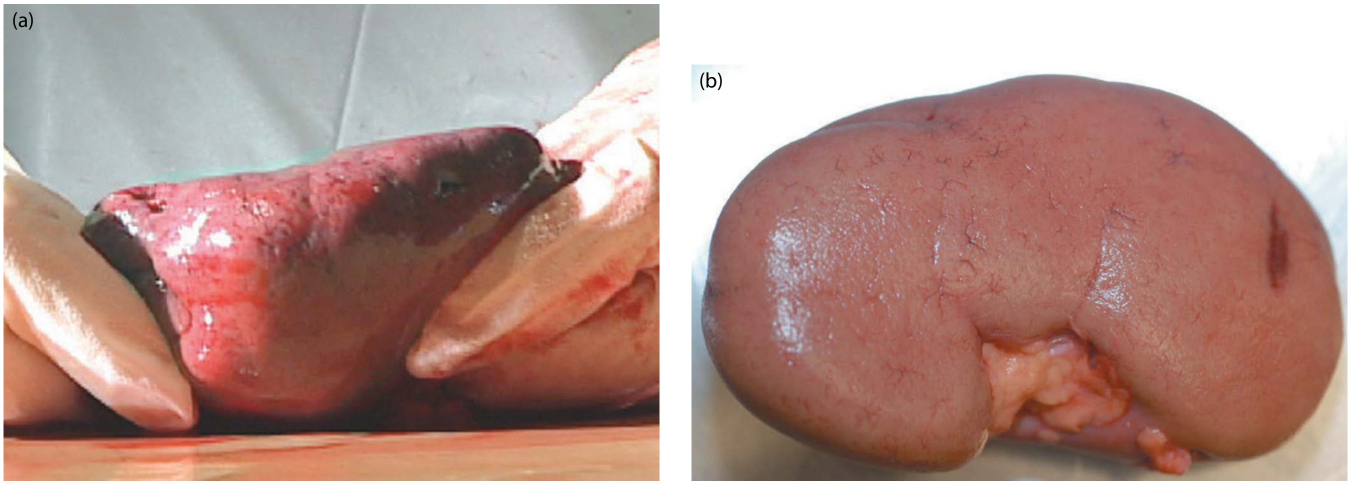


Figure 8.69 Left and right kidneys. (a) The pathologist is holding a normal left kidney, which has a delta or triangular shape. This shape is thought to result from the spleen molding the superior pole of the kidney. **(b)** The normal right kidney is bean-shaped and should have a smooth outer covering, or cortex. The main functions of the kidneys are to help regulate blood pH and blood pressure, filter blood, and remove excess salts, water, and products of protein metabolism. The waste product of these processes is, of course, urine.

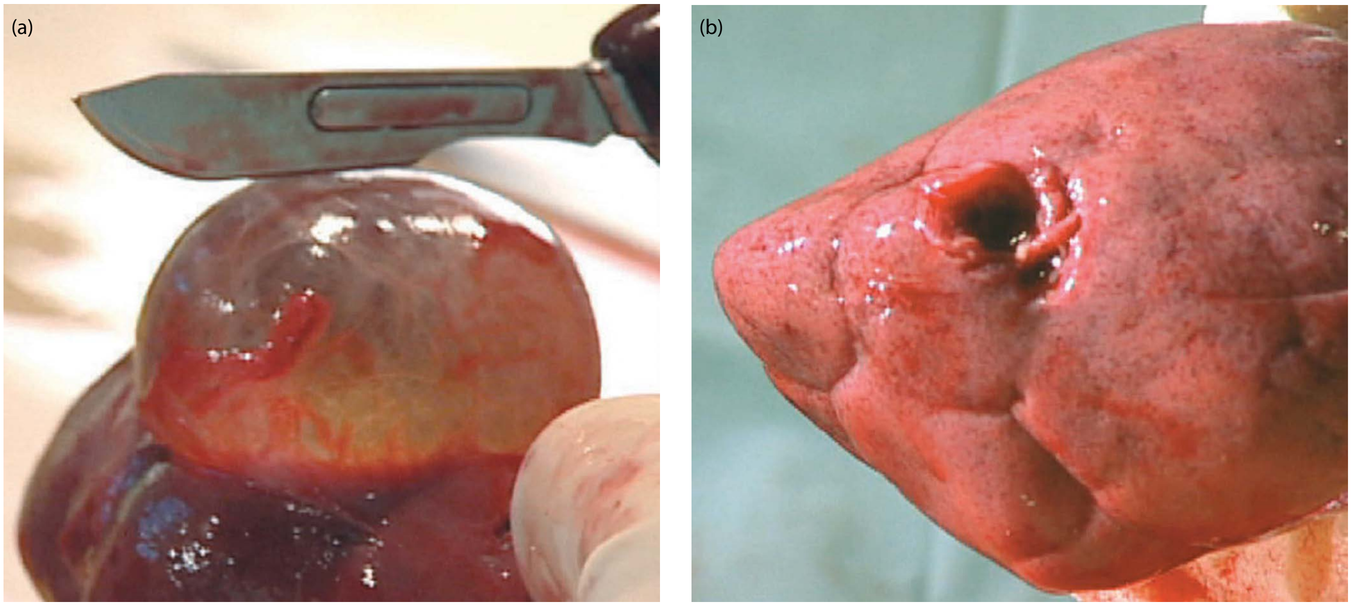


Figure 8.70 Cortical cyst of the kidney. (a) The cortex of this kidney has a large fluid-filled cyst. **(b)** This crater represents a cyst that burst open upon removal.

Figure 8.71 Renal arteriolosclerosis. This kidney has a pitted, granular surface. This condition is called arteriolosclerosis; it is a result of hypertension, which causes local ischemic changes in the small vessels near the outer surface, or cortex. Part of the outside of the kidney scars, while adjacent tissue survives, causing pitting of the surface (see Figure 10.19).

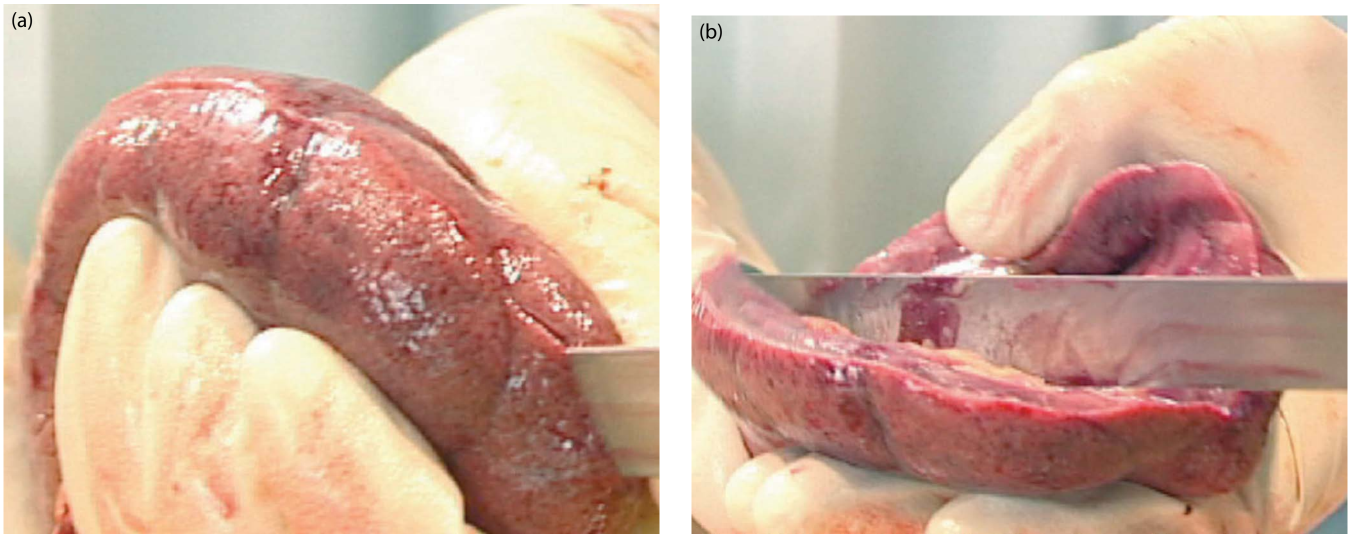
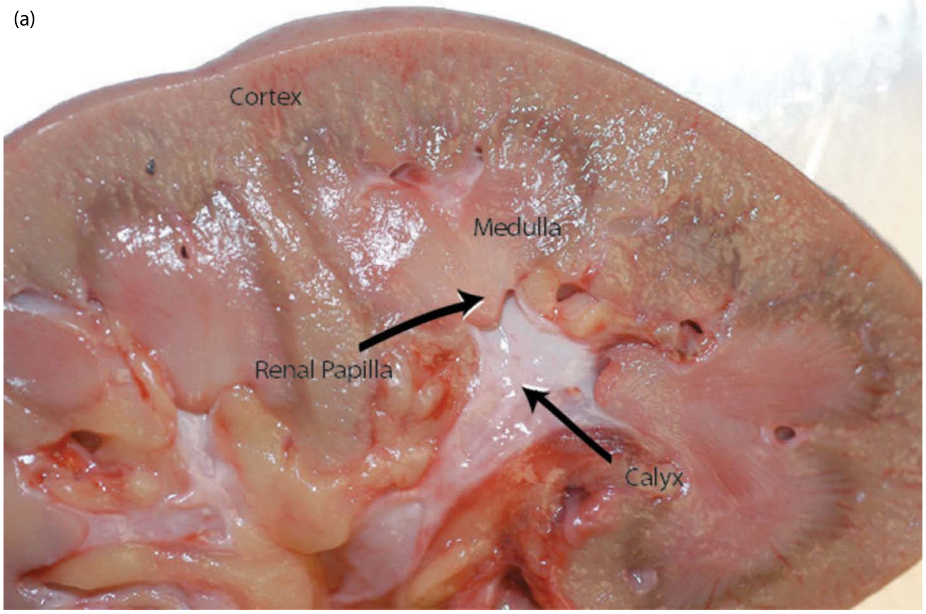


Figure 8.72 Dissection of the kidney. (a) The kidney is cut along the long axis, or "bivalved." **(b)** This type of cut enables a central view of the cortex (blood-filtering glomeruli), medulla (tubules), and calyces (urine-draining portions) of the kidney.



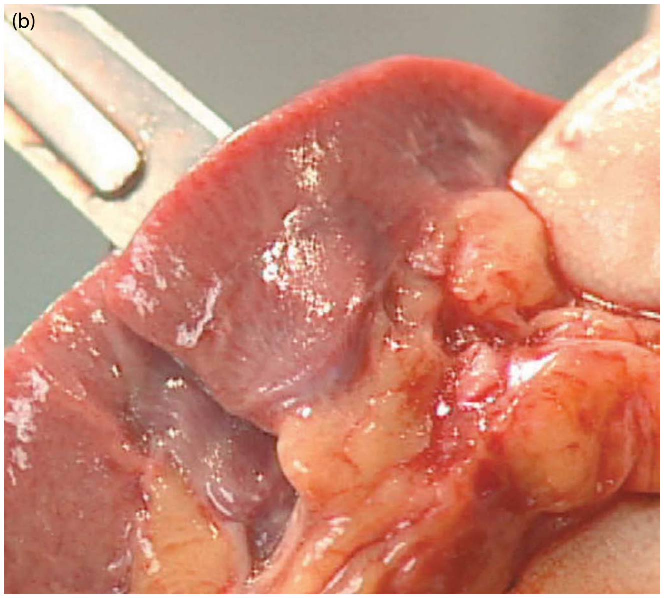


Figure 8.73 Cross-section of the kidney. (a) The blood is filtered through the glomeruli, which are largely present in the cortex. In conditions such as diabetes and hypertension, these glomeruli can become sclerosed (scarred), and if significant numbers of glomeruli are sclerosed, renal failure can result. The medulla and papillary tip largely contain tubules, which drain the urine. Inflammation of this area is called pyelonephritis. **(b)** A section is taken of the outer cortex, medulla, and papillary tip for microscopic review.

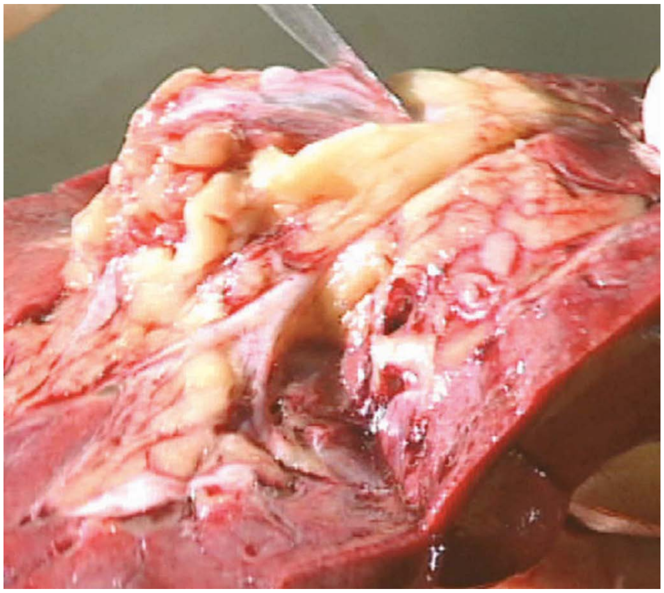


Figure 8.74 Opening the calyces. The papillary tips drain into a calyx, which, in turn, drains into the renal pelvis and then the ureter. The renal pelvis and calyces are opened. Tumors or stones can be found there.

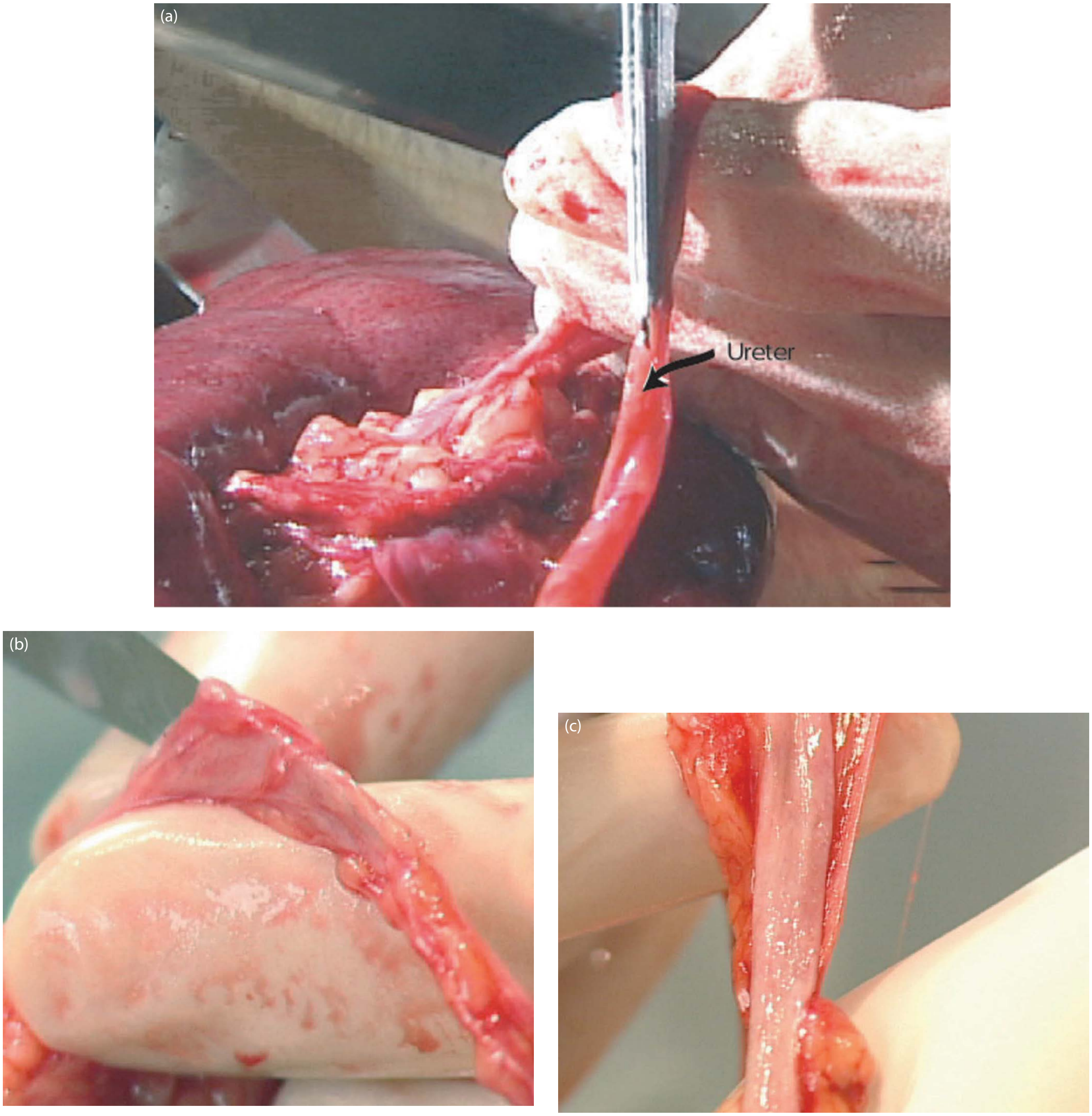


Figure 8.75 (a–c) Opening the ureter. The ureter is opened to look for stones, tumors, or inflammation.

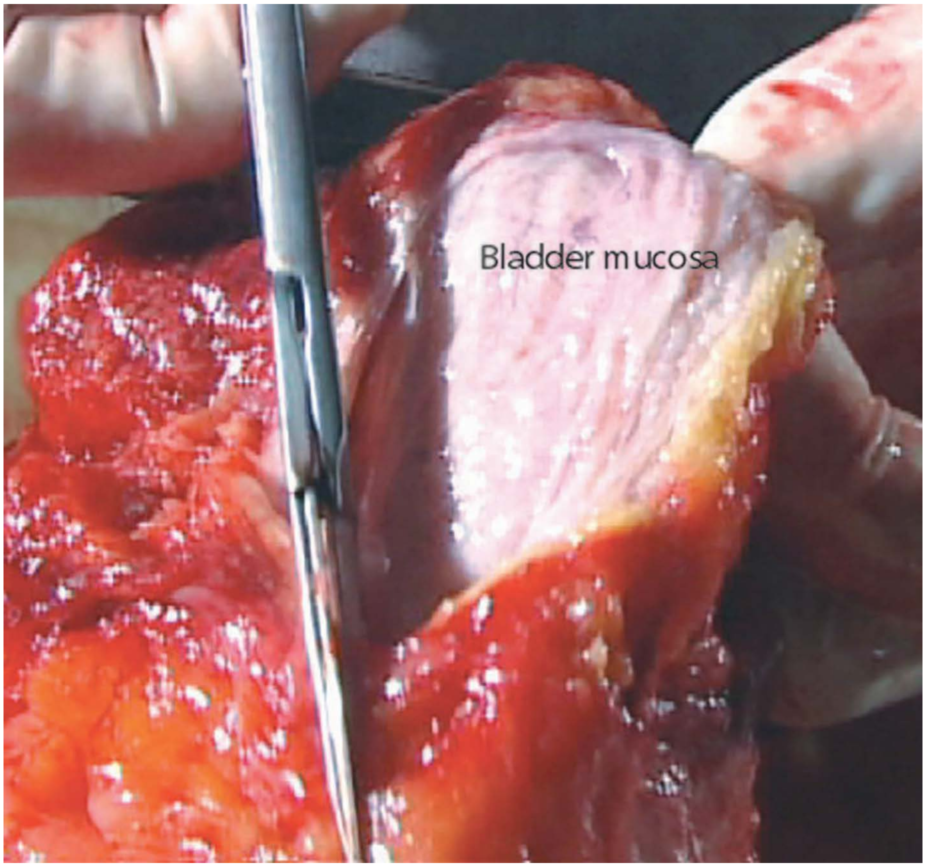


Figure 8.76 Opening the bladder. The dome of the bladder is opened, exposing the pink mucosa below. The urine has been removed.

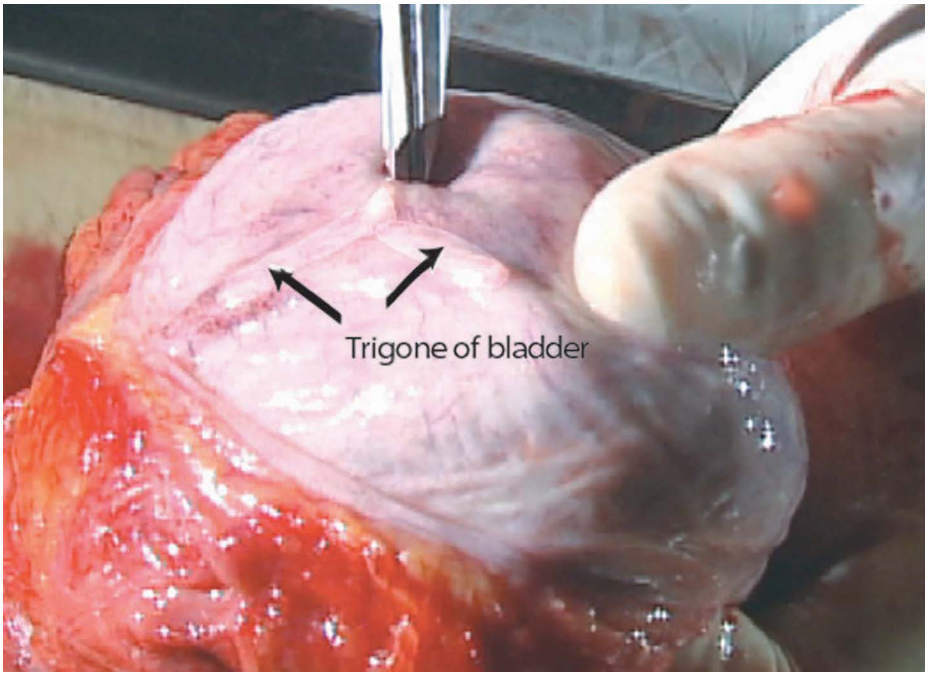


Figure 8.77 Bladder trigone. The scissors are in the urethra of the bladder. Note the triangular area, the trigone, just in front of the urethra (arrows). The ureters empty into the bladder at the ends of the trigone.

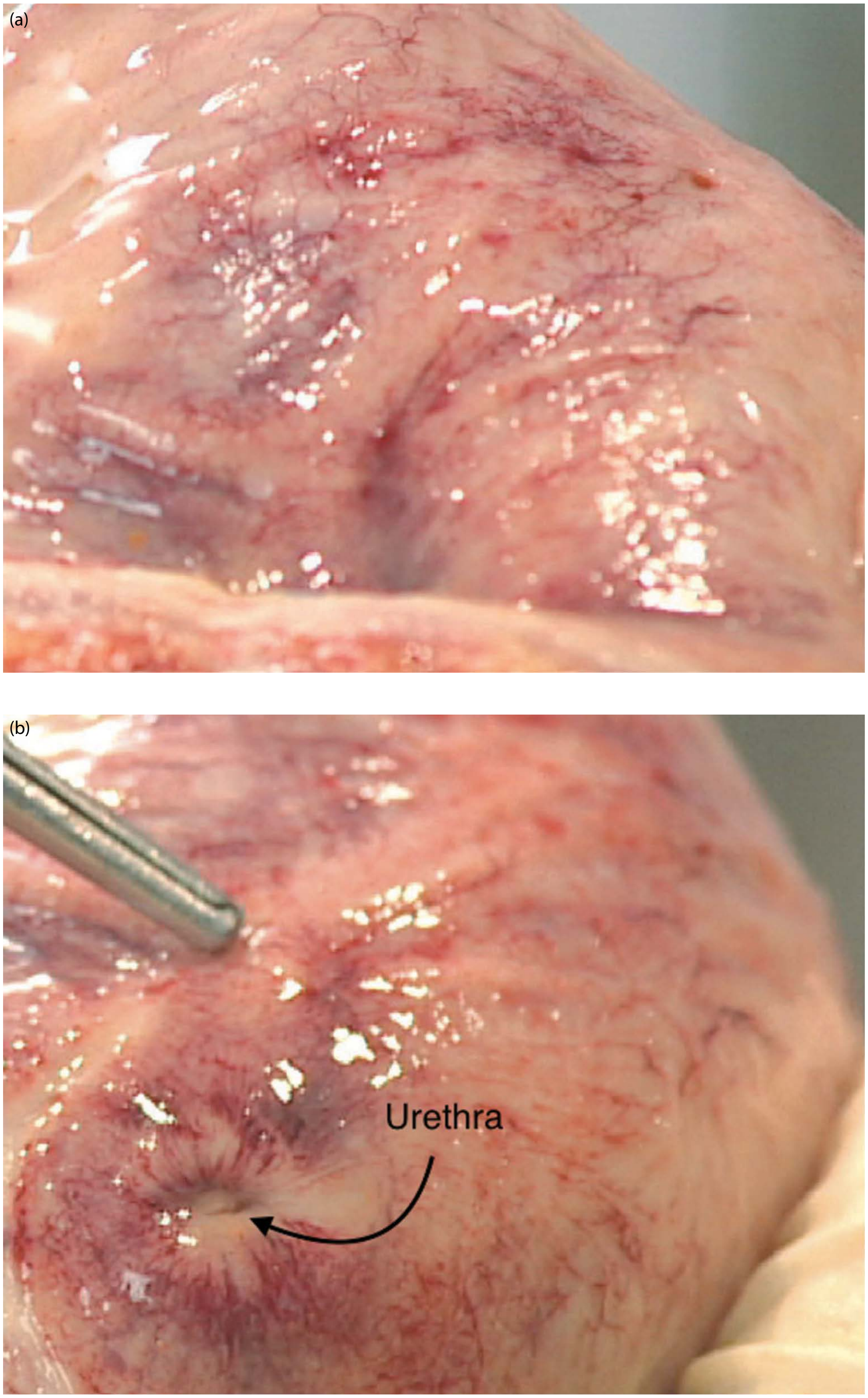
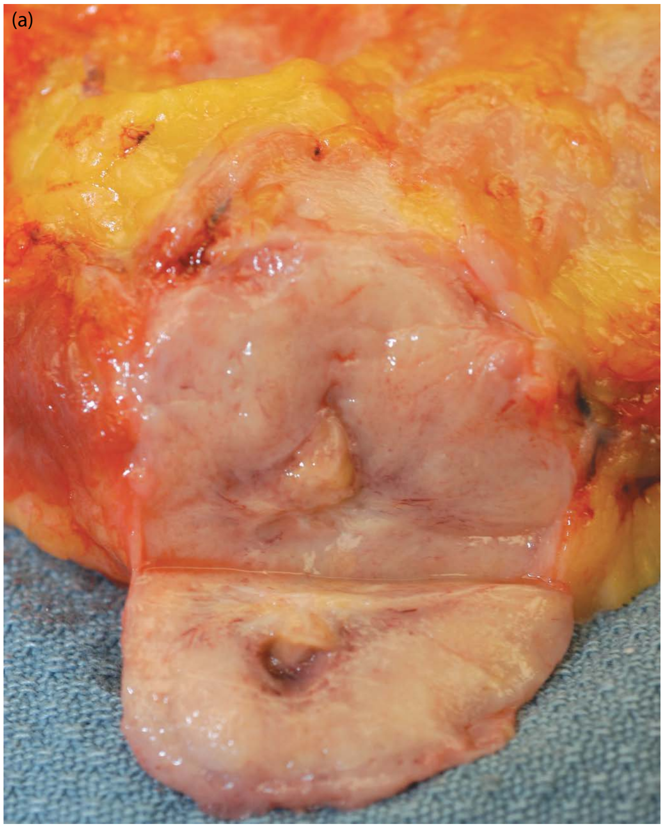


Figure 8.78 Bladder erythema and urethral opening. (a) This close-up of the bladder shows reddened mucosa, and multiple small blood vessels are prominent. This erythema can indicate inflammation. **(b)** The inflammation is particularly prominent near the urethral opening.



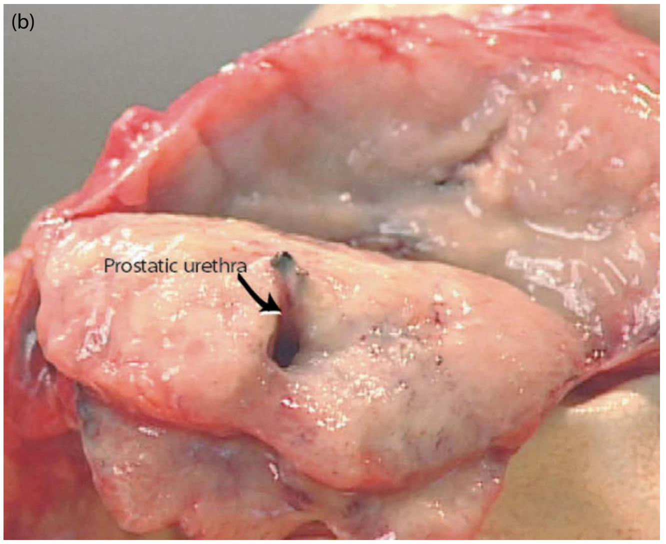


Figure 8.79 Prostate sectioning. (a) The base of the prostate is attached to the bladder. The prostate is serially sectioned. **(b)** The opening in the cut prostate is the portion of the urethra that courses through the prostate, or the prostatic urethra. The pathologist searches for carcinoma and inflammation.

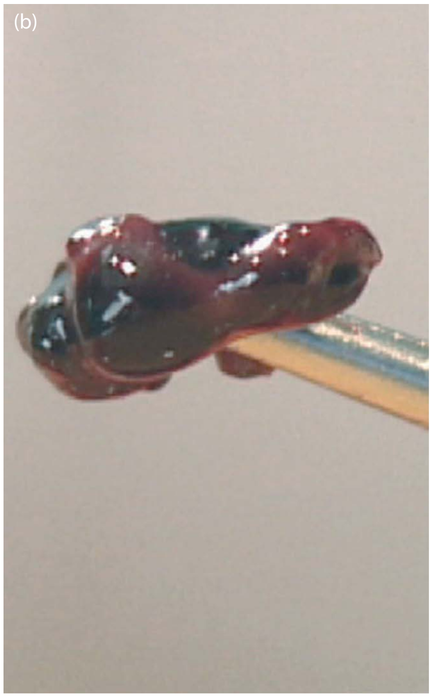


Figure 8.80 (a and b) Prostatic thrombi. This prostate has a few thrombi which, when pulled out, retain their shapes. These are like premortem thrombi. This patient had lung cancer. Patients with many cancers are susceptible to thrombosis.

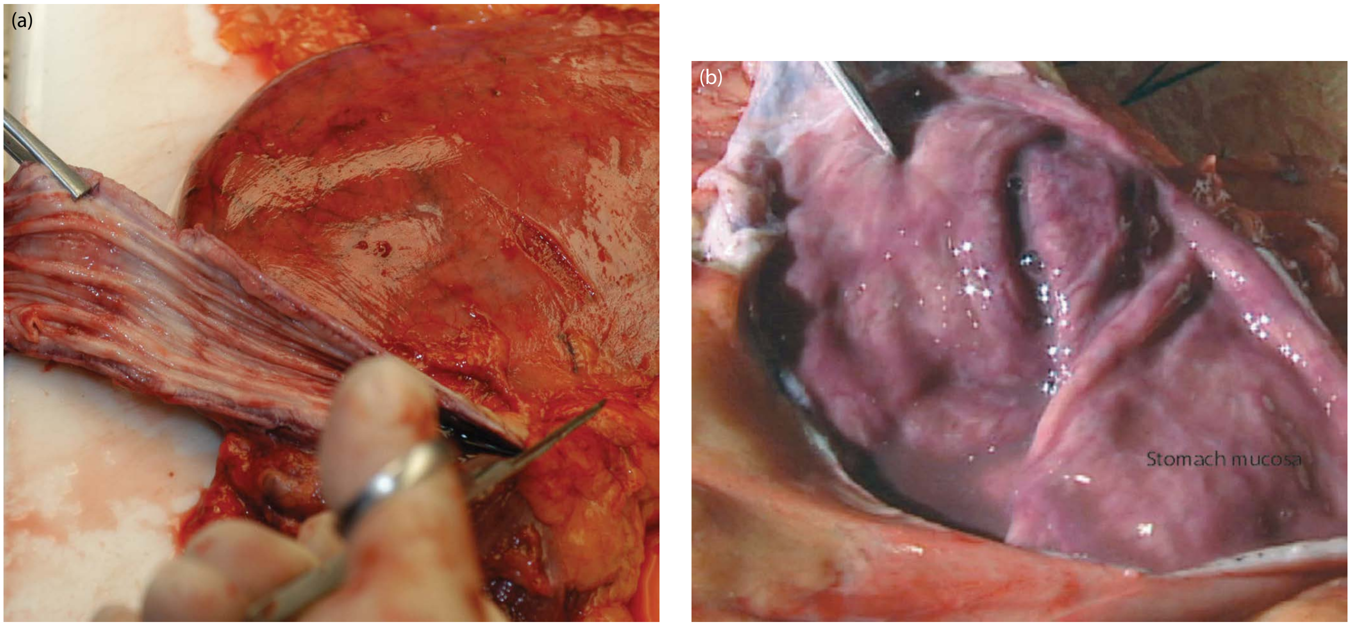


Figure 8.81 (a and b) Opening of the esophagus and stomach. The esophagus is opened with the scissors to expose the stomach mucosa.

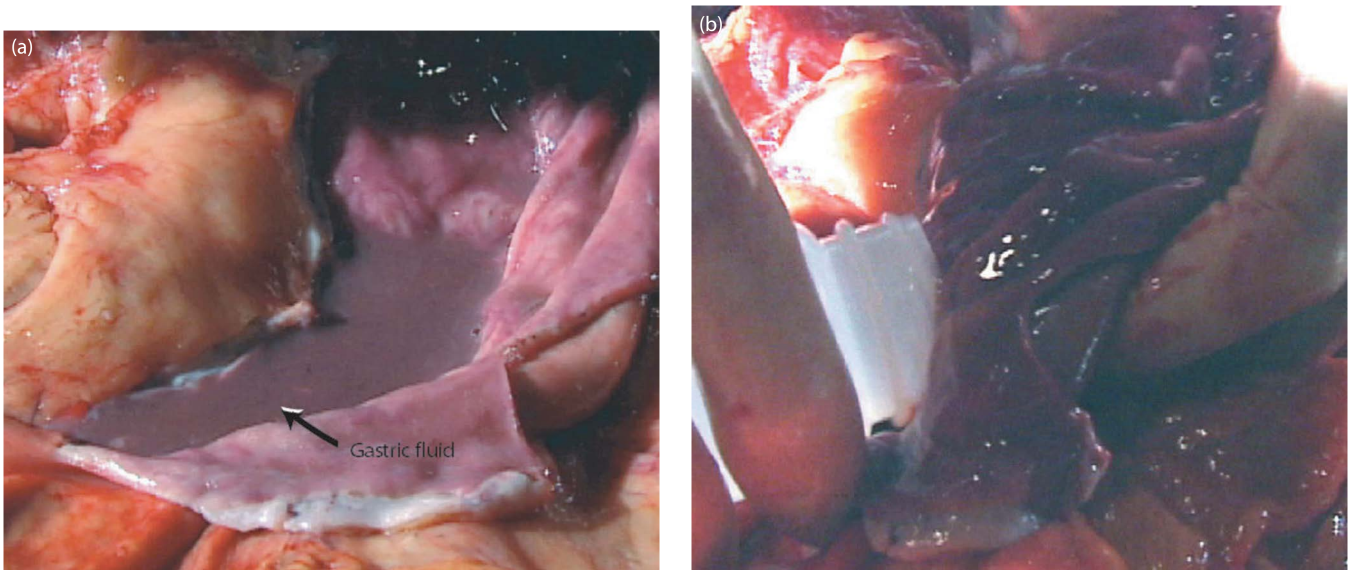


Figure 8.82 (a and b) Obtaining gastric fluid. Gastric fluid is taken for analysis in a clean plastic container.

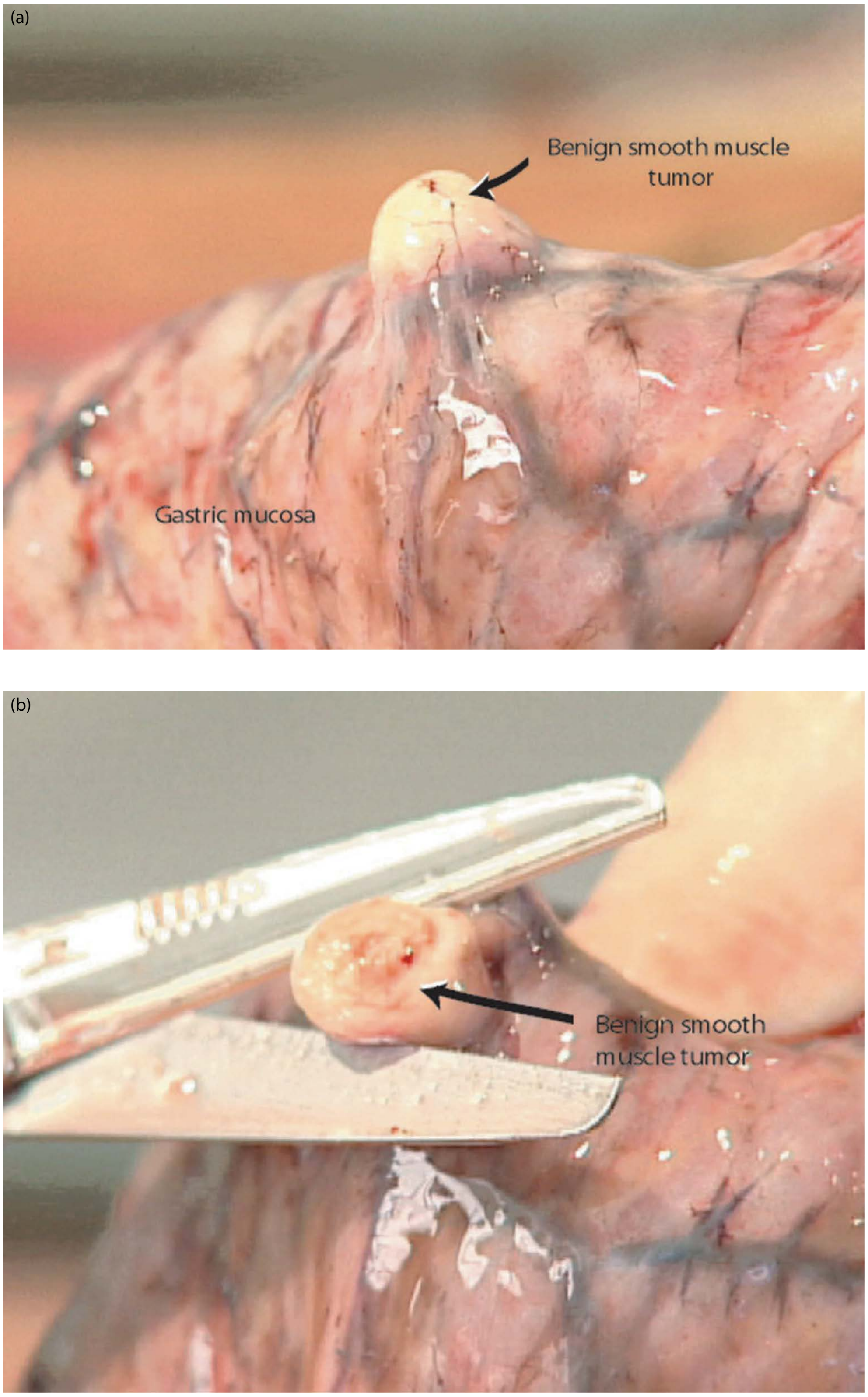


Figure 8.83 Benign stromal tumor of the stomach. (a) This nodule is seen in the mucosa. **(b)** Cutting the nodule shows that it is round and firm. This lesion is a benign gastrointestinal stromal tumor of muscle origin.

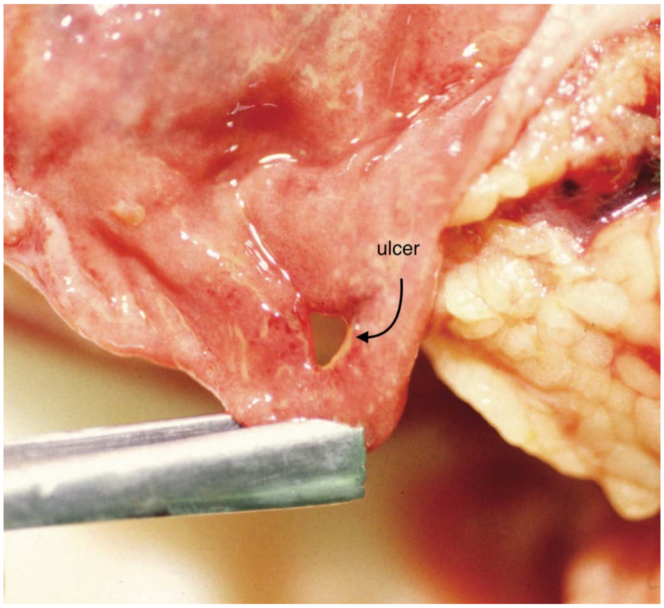


Figure 8.84 Perforated gastric ulcer. A gastric ulcer can be seen above the forceps. The ulcer has gone through the mucosa, muscular wall, and serosa (outer covering). The stomach contents then leaked into the peritoneal cavity, causing severe inflammation and infection (peritonitis). Prompt surgical repair of the stomach might have prevented the death.

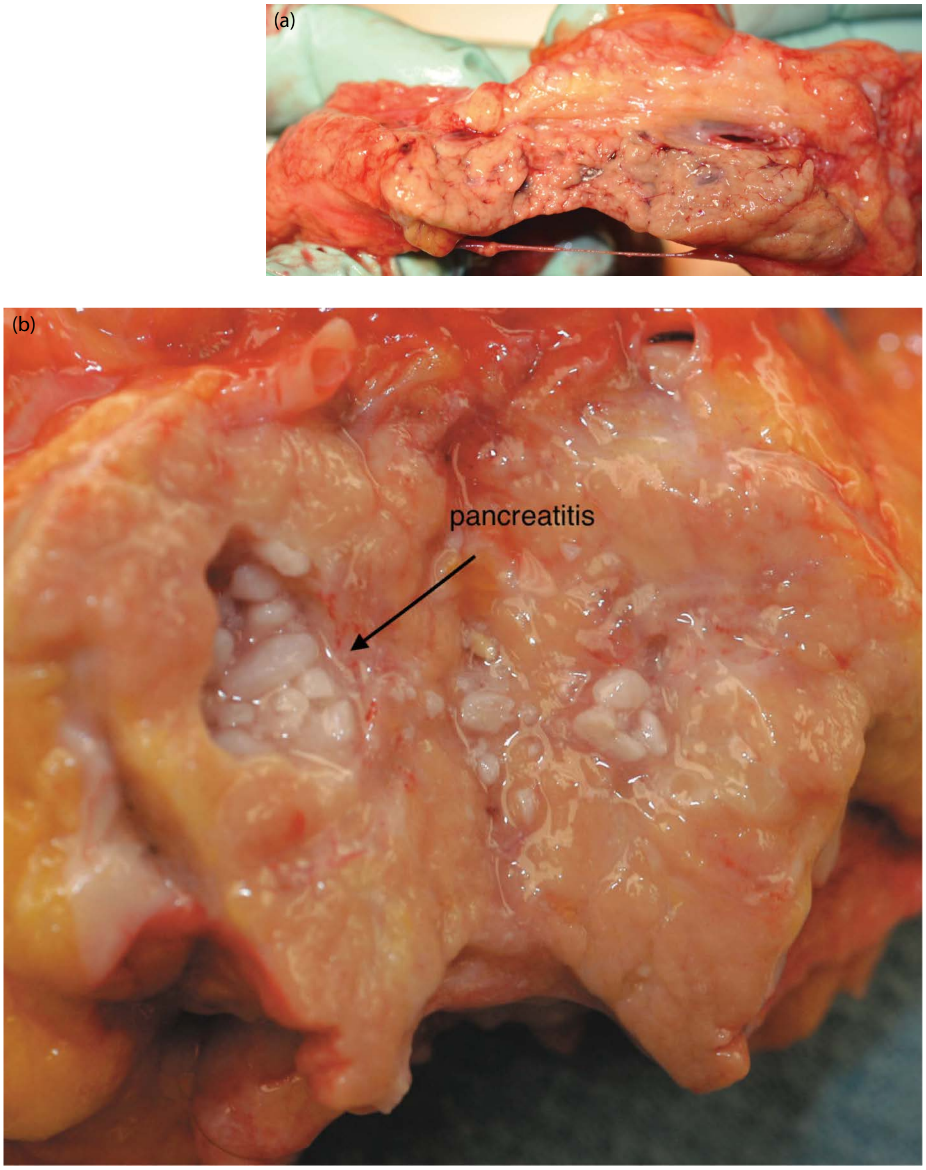


Figure 8.85 (a) Pancreas. The pancreas is sectioned to display the normal lobular appearance. The pancreas secretes enzymes that are used in digestion into the gastrointestinal tract and releases insulin, glucagon, and somatostatin into the blood. **(b) Chronic pancreatitis.** Pancreatitis is a condition commonly associated with alcohol abuse. In acute pancreatitis, the pancreas becomes inflamed and digestive enzymes can be released into the tissues, causing hemorrhage that sometimes results in shock or death. This image depicts a hard, chronically inflamed pancreas with the formation of an inflammatory pseudocyst and calcification, as seen just left of center.

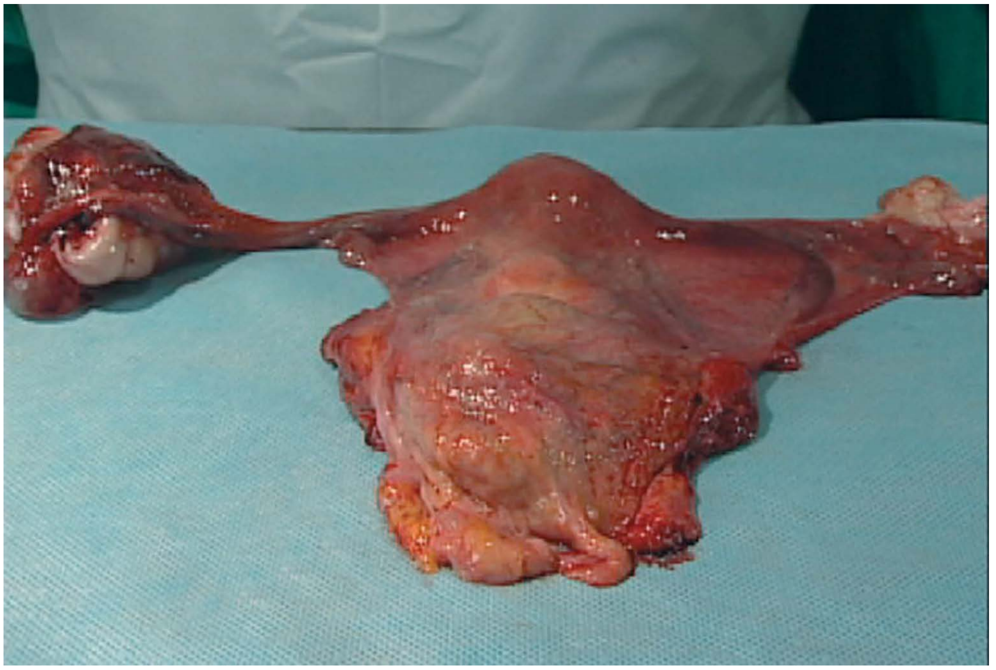


Figure 8.86 Uterus with ovaries and fallopian tubes. The uterus, ovaries, and fallopian tubes are displayed. Note the large ovary in the left corner of the figure (also seen in Figures 6.35a, 6.35b, and 7.46b).

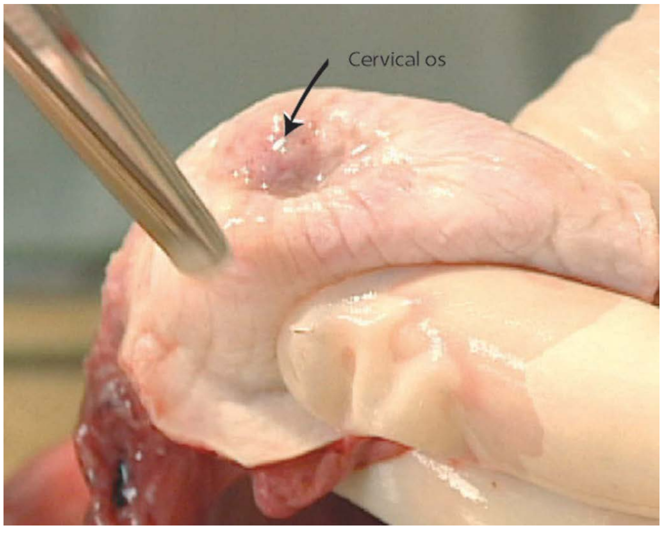


Figure 8.87 Cervix uteri. The cervix is displayed with the cervical opening or "os" in the center. This is the site where cervical dysplasia and carcinoma can occur.

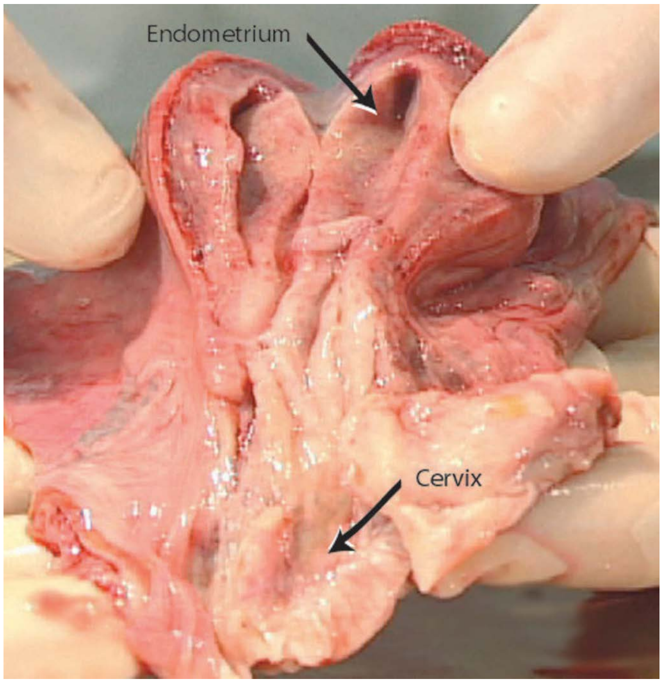


Figure 8.88 Uterus opened. The uterus is opened, exposing the endometrium. The endometrial cavity is examined for tumors. The presence or absence of pregnancy is noted. Samples can be taken from deceased fetal tissue in order to determine paternity.

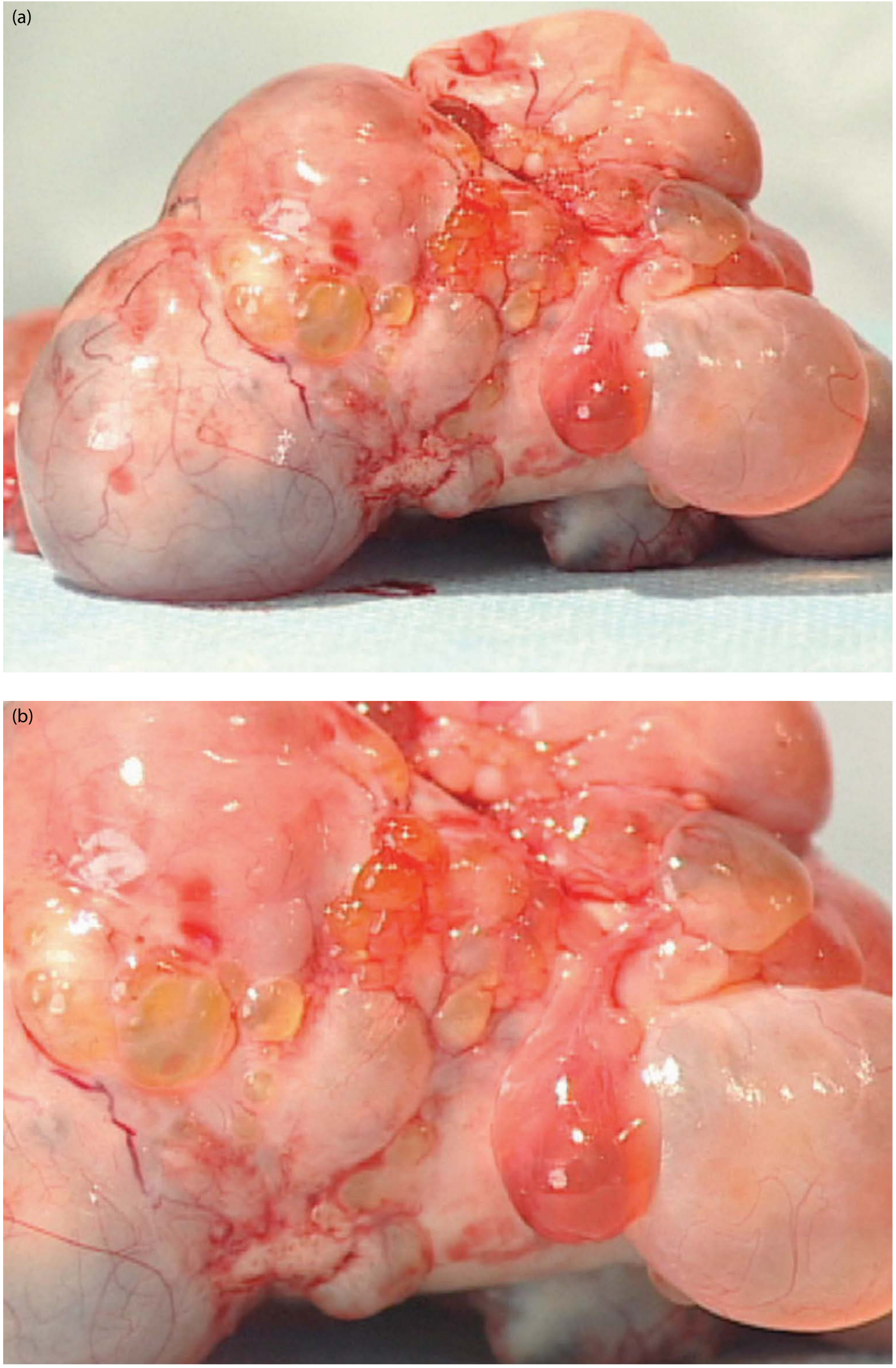


Figure 8.89 Ovarian serous cystadenoma. (a) This large cyst is approximately 8.0 cm (over 3 inches) in diameter and was likely to have caused pelvic pain and discomfort during life. **(b)** A close-up shows it to be a complex cyst with multiple smaller cysts attached to the larger cyst wall.

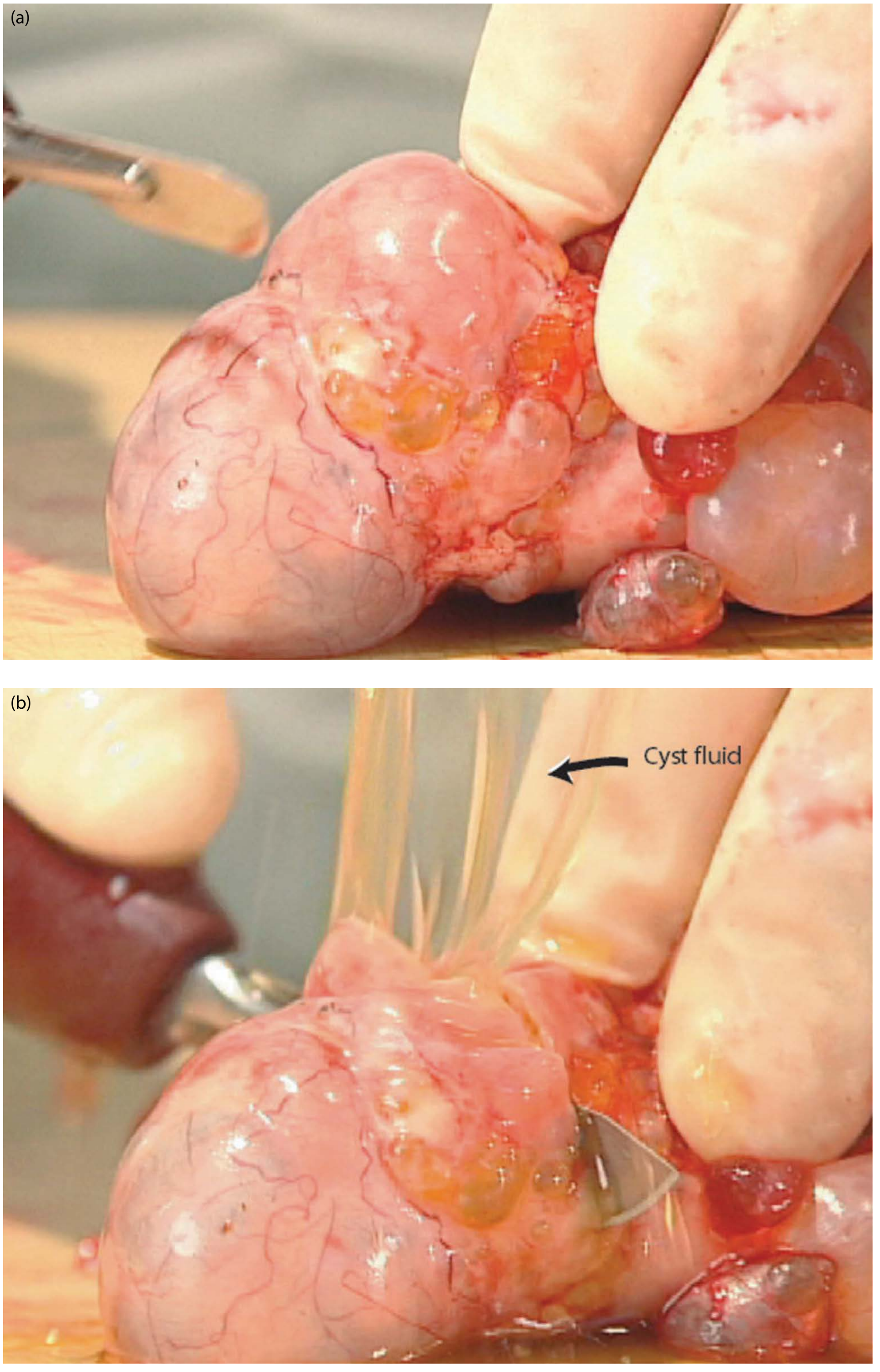


Figure 8.90 Dissecting ovarian serous cystadenoma. (a) The complex cyst has a smooth wall, although it is cavernous and complex. **(b)** When this cyst is cut, a yellow-colored fluid exudes from within. This fluid is under pressure and can squirt bystanders in the face (remember universal precautions). Microscopically, this cyst proved to be a serous cystadenoma, a benign tumor.

CHAPTER 9

EXAMINATION OF THE HEAD, SKULL, BRAIN, AND SPINAL CORD

All medical–legal examinations require the examination of the head, skull, and brain. This includes careful examination of the scalp, skull, and dura mater, the fibrous membrane that tethers the brain in place. Since the brain is the supreme organ system, giving orders to the rest of the body, no examination is complete without assessment of the brain and its coverings. At times, the following question is raised: "Why does the head need to be examined when the cause of death is obvious?" Aside from the reasons given in Chapter 2 for performing an autopsy when the cause of death is "obvious," additional reasons for examining the head are listed below:

- The scalp and hair can hide contusions and other injuries. Examining the scalp from the bottom side can make these injuries evident.
- Postmortem skull x-rays often do not show small fractures.
- In the author's experience, computerized axial tomography scans of the head performed on the injured person can miss up to 10 cc of subdural blood.
- Unexpected conditions such as tumors, old injuries, inflammation (e.g., meningitis), strokes, or other conditions are often found.
- A common injury seen in forensic pathology practice is the subdural hematoma. Often, the mechanism of sustaining a subdural hematoma is falling on a hard surface. Small blood vessels between the dural layer and the brain (bridging vessels) are severed, causing bleeding and hematoma. The brain must be examined for this injury (Figure 9.9a–d).

The reader should follow Figures 9.1 to 9.27 to see the removal and dissection of the brain and spinal cord, along with common associated injuries and conditions. (See Video 9.1.)

Figure 9.1 (a and b) Incising the scalp. The scalp skin, subcutaneous tissue, and galea aponeurotica (thick fibrous layer) are cut down to the bone. The cut is started behind the ear, extended around the vertex (top of the head), and completed behind the other ear.

Figure 9.2 (a–c) Lifting the scalp and galea aponeurotica. The galeal layer is peeled from the periosteum of the bone.

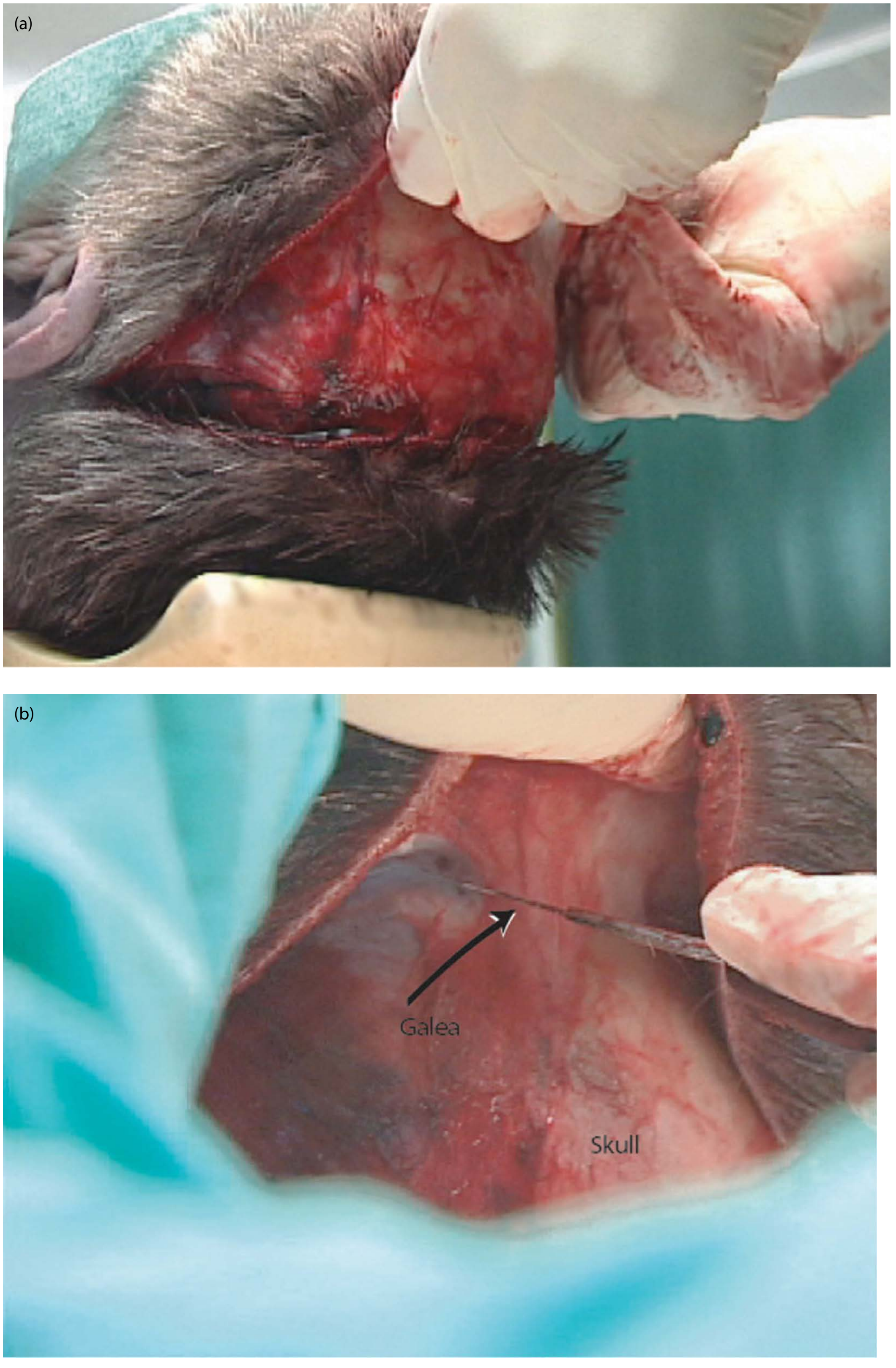


Figure 9.3 (a and b) Reflecting the scalp back. Once the scalp is reflected back, a scalpel is used to dissect the attached fibrous soft tissue.

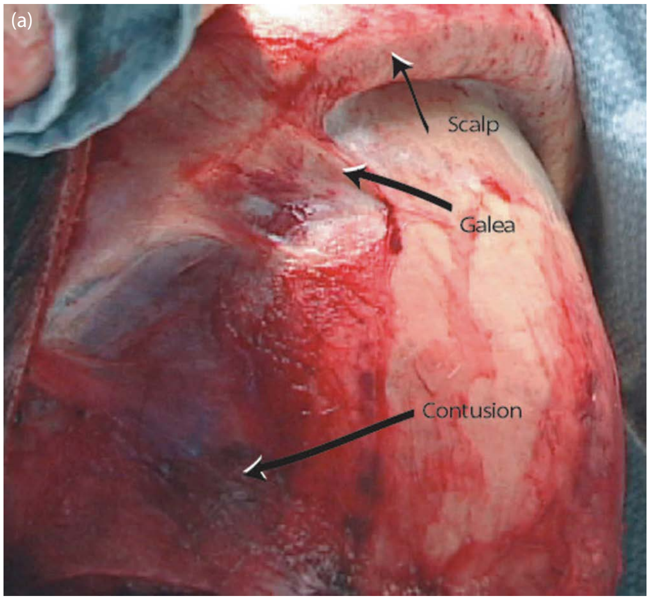


Figure 9.4 Scalp hemorrhage. (a) The scalp is reflected back as the remaining strands of soft tissue are cut. As the scalp is reflected back, a contusion is seen as a darkened area just below the scalpel. **(b)** The involved soft tissue is cut, showing the underlying contusion hemorrhage.

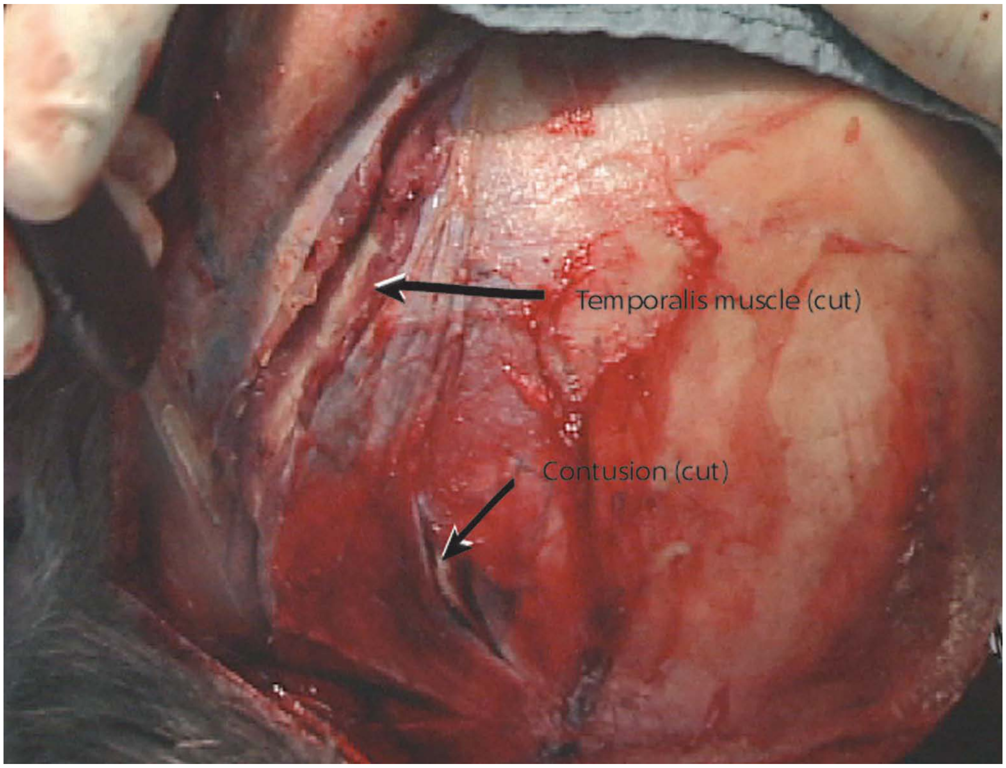


Figure 9.5 Cutting the temporalis muscle. The temporalis muscle is cut to prepare the skull for sawing. The saw blade does not cut soft tissue efficiently. A small contusion is seen at the arrow. This individual fell and then became unresponsive, having suffered a myocardial infarction.

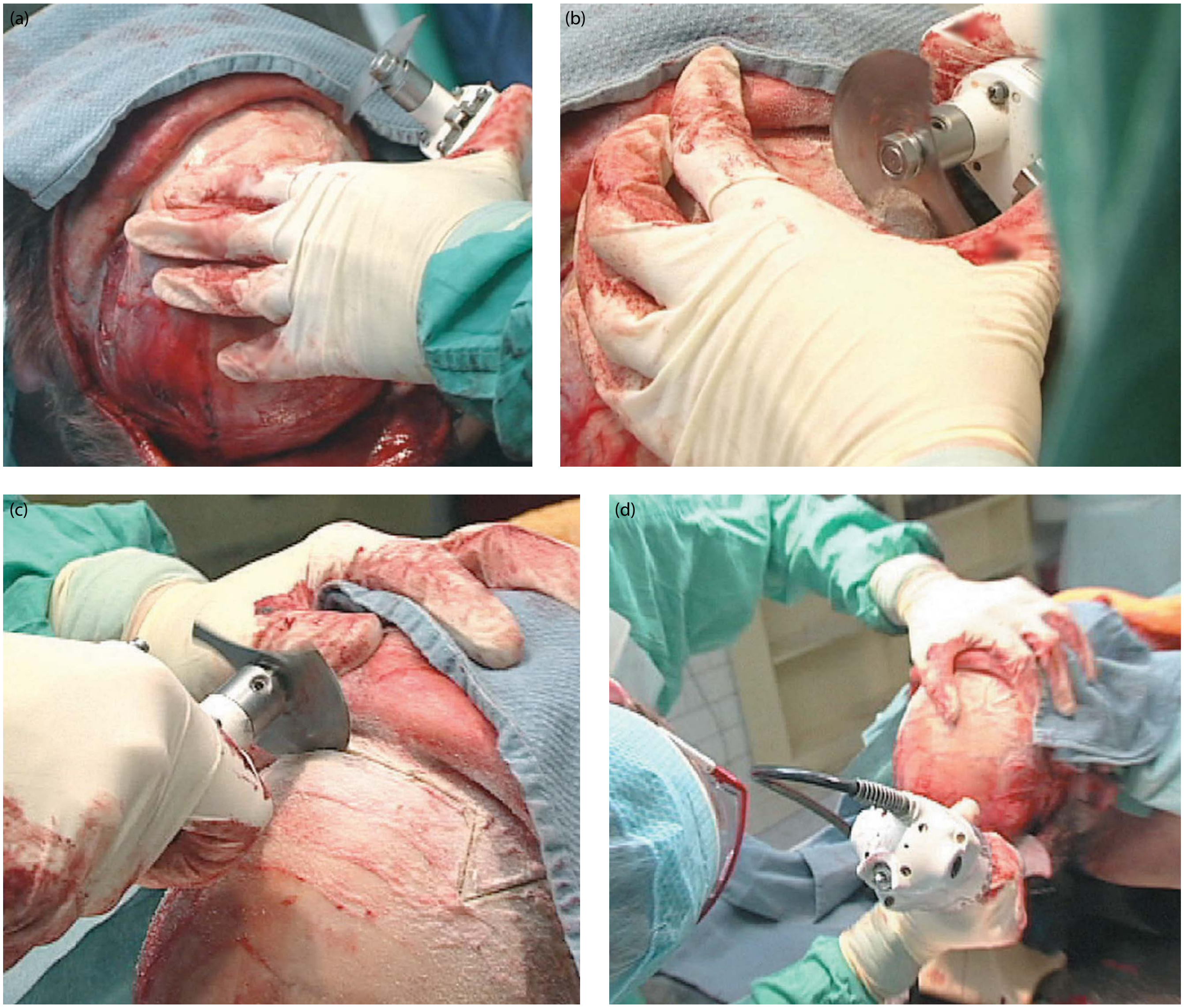


Figure 9.6 (a–d) Sawing the skull. The skull is sawed circumferentially. Care is taken not to saw too deeply, which could alter the brain surface.

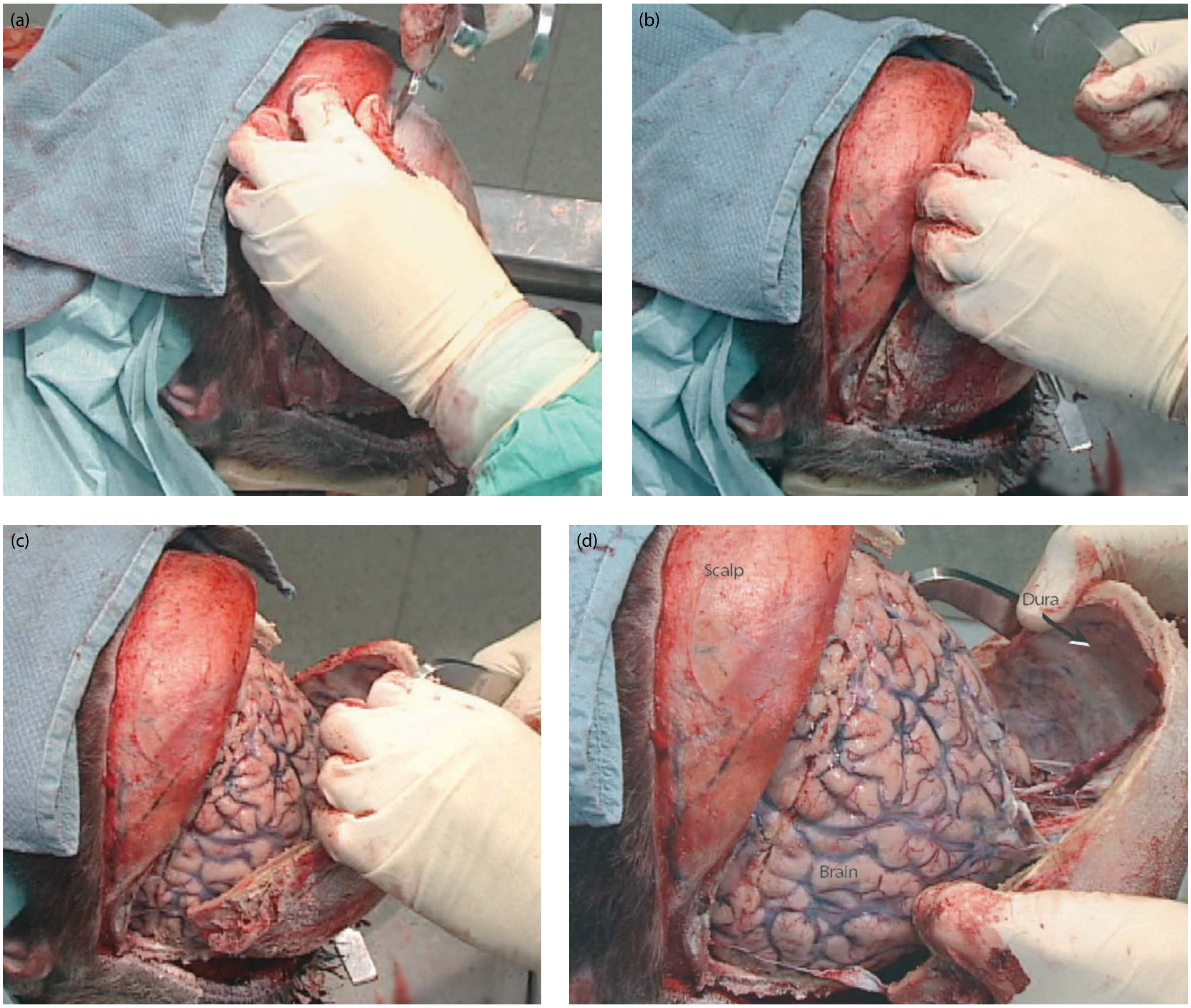


Figure 9.7 Opening the skull. (a–c) The opened portion of the skull (calvarium) is detached from the base. The pathologist is careful to look for hemorrhage above (epidural) or below (subdural) the dura mater. **(d)** The dura mater is the tough gray membrane indicated by the arrow.

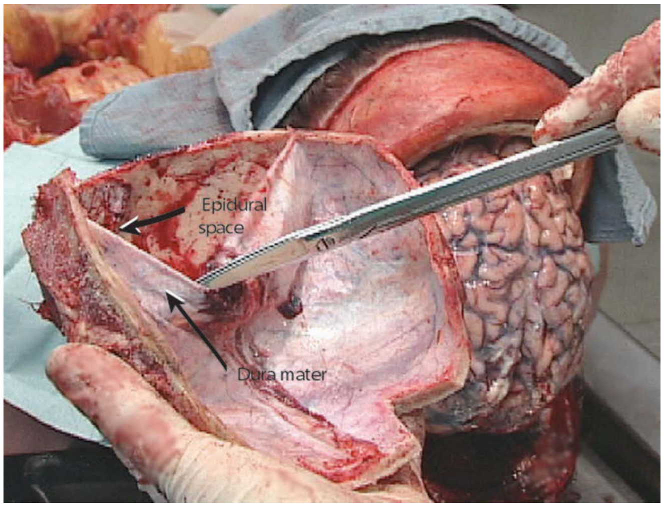


Figure 9.8 Examination of the dura. The top portion of the skull (calvarium) is examined here. The gray membrane is the dura mater. The dura mater has been partially stripped away from the skull. The tip of the scissors is in the epidural ("above the dura") region. The subdural space is the region below the dura.

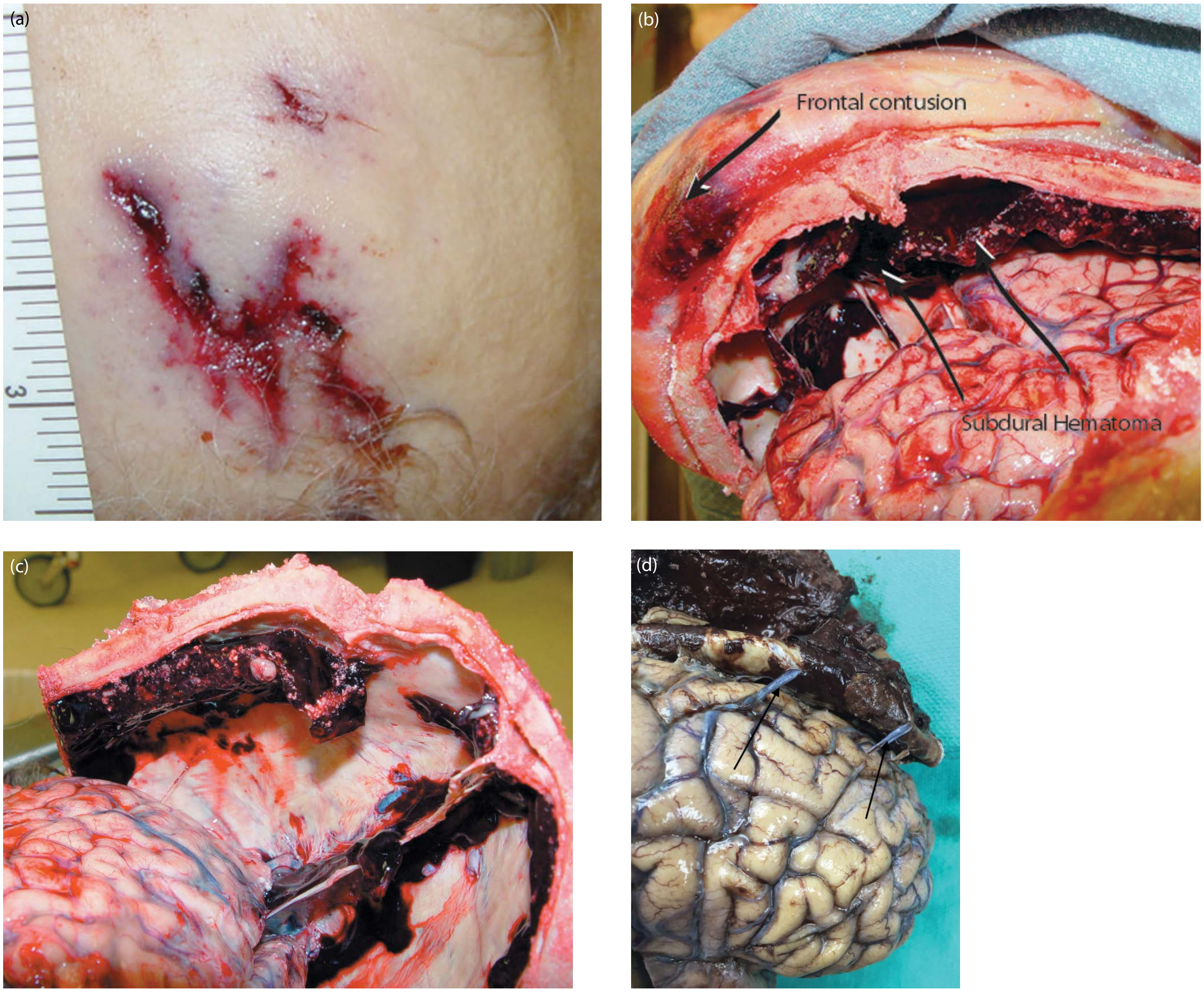


Figure 9.9 (a–d) Laceration of head with subdural hematoma. A large hematoma can be seen between the brain and the dura, shown by the arrows. The pressure of the hematoma can affect the function of the brain, resulting in coma and death. This hematoma was produced by the decedent falling and striking his forehead. The small veins bridging the dura and the brain were torn during the fall, resulting in hemorrhage. **(d)** Dural bridging veins. These small, delicate veins can be torn during a head injury and produce a subdural hematoma.

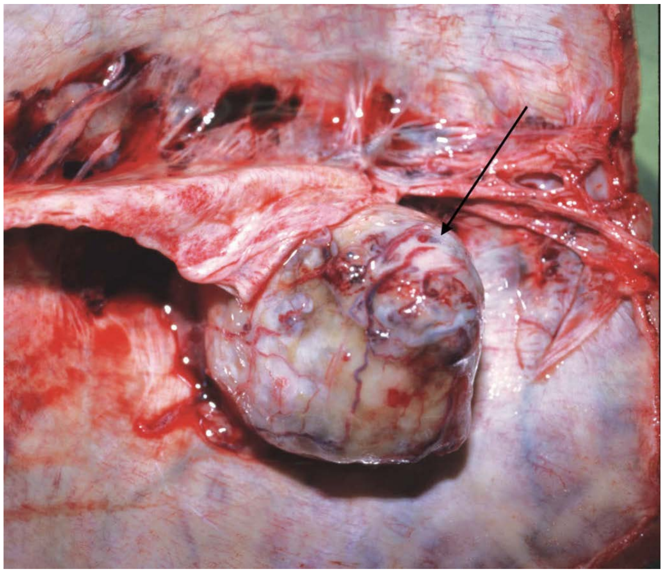


Figure 9.10 Meningioma. Tumors can be attached to the dura. The large, golf ball-sized tumor seen here is a benign tumor called a meningioma. Even though benign, the tumor occupies space in the closed area of the brain. As a result, the tumor can press on vital parts of the brain, causing symptoms related to these areas of the brain. Many of these tumors do not cause symptoms and are found incidentally at the autopsy.

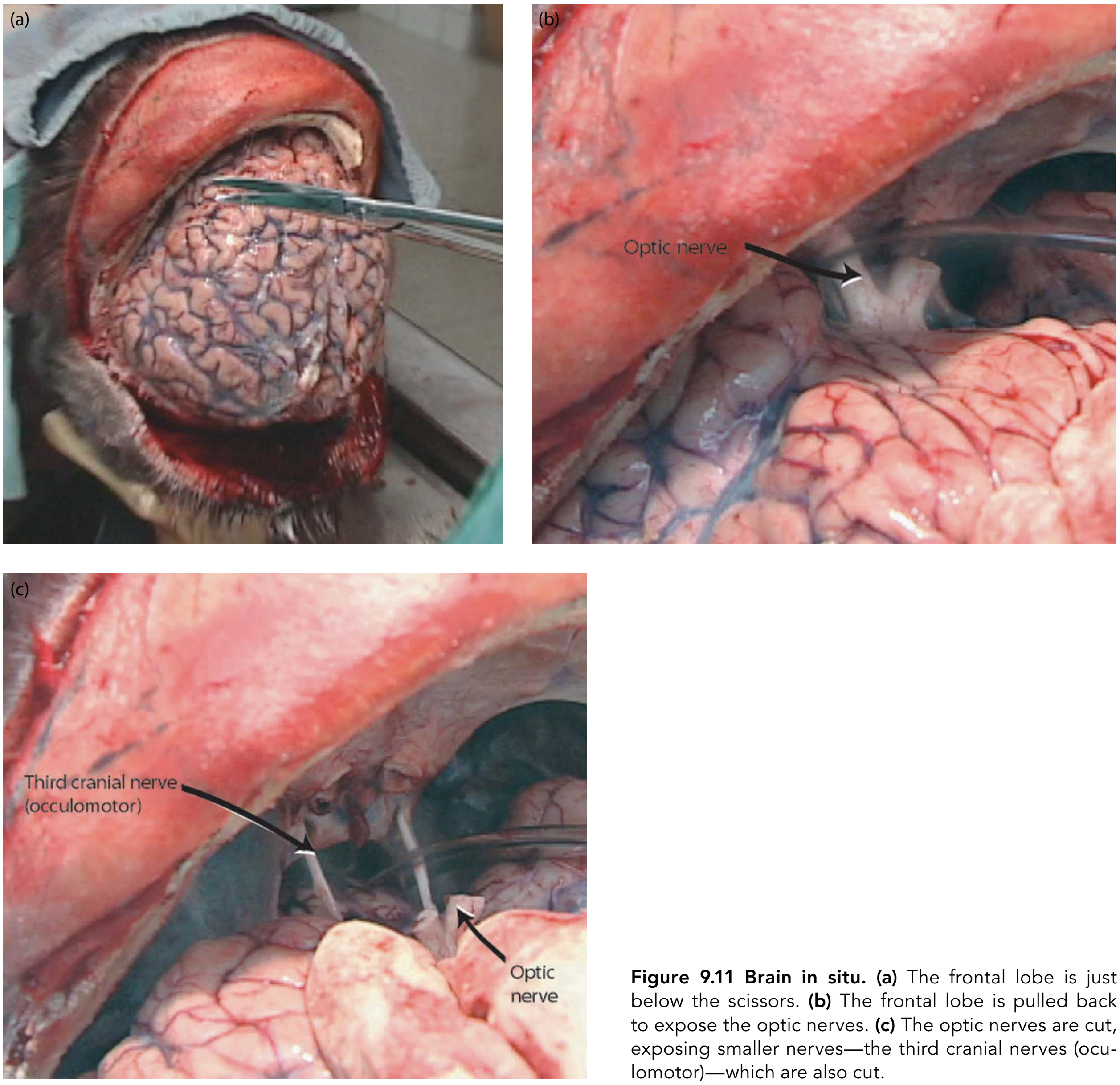


Figure 9.11 Brain in situ. (a) The frontal lobe is just below the scissors. **(b)** The frontal lobe is pulled back to expose the optic nerves. **(c)** The optic nerves are cut, exposing smaller nerves—the third cranial nerves (oculomotor)—which are also cut.

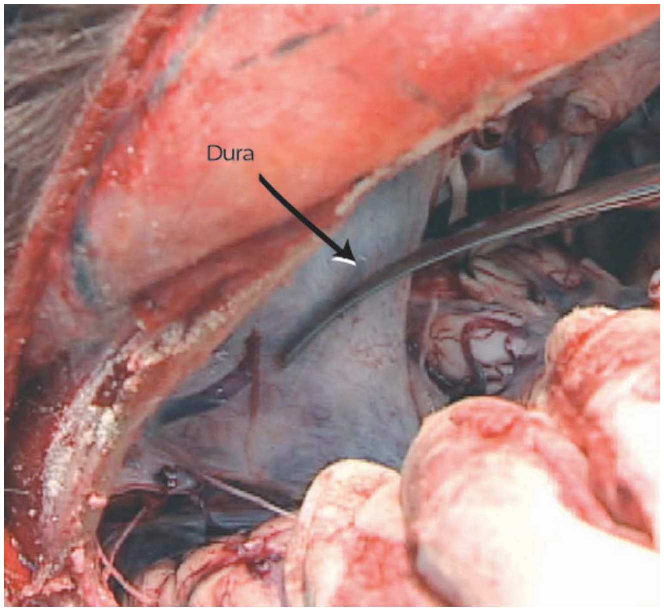
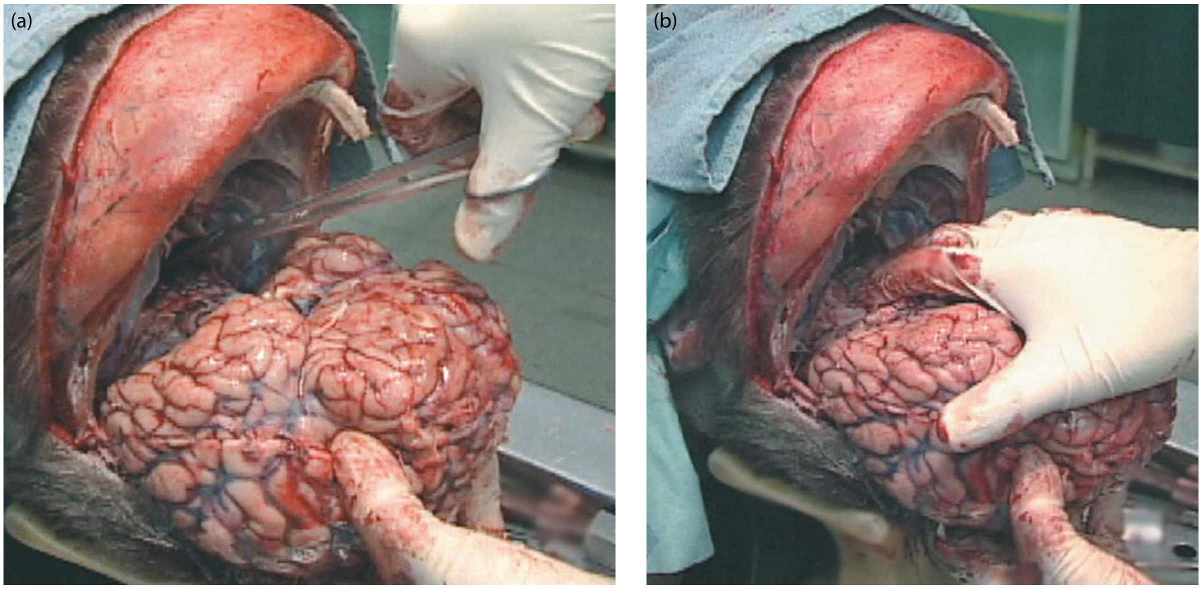


Figure 9.12 Cutting the tentorium cerebelli. The dural membrane covering the cerebellum is cut to reveal the cerebellum below. The cerebellum is an area of the brain dealing with the coordination of muscles and balance.



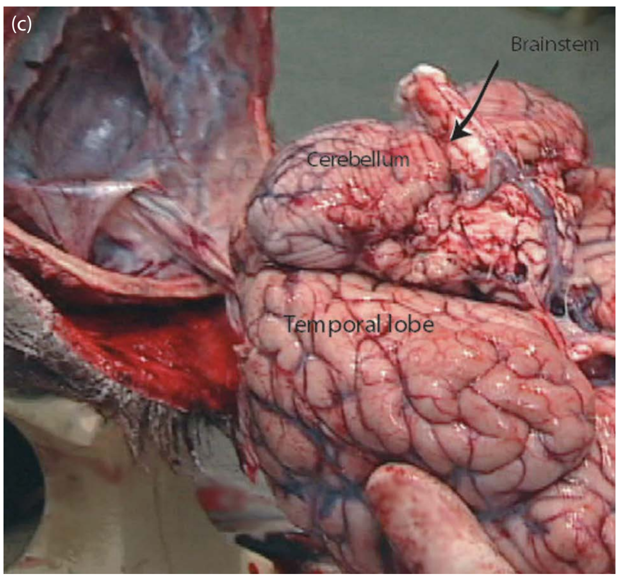


Figure 9.13 (a–c) Removing the brain. The brainstem is cut and the brain is removed.

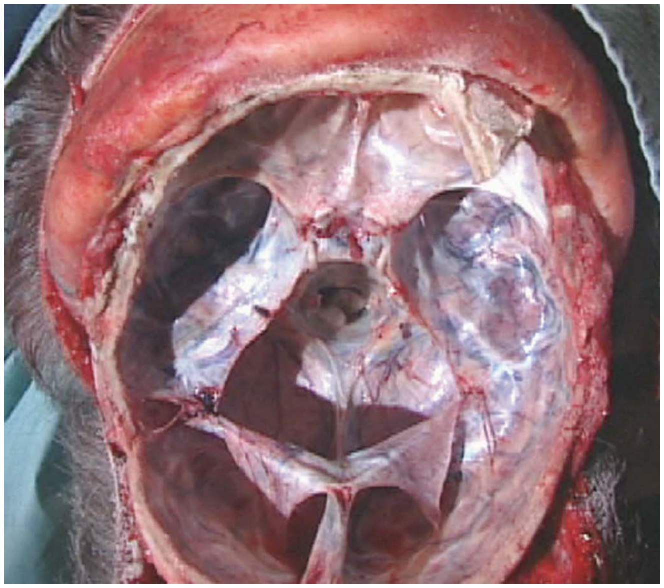


Figure 9.14 Base of the skull. The skull is seen with the dura attached. The dura is then peeled off to check the base of the skull for fractures. Direct examination of the base of the skull for fractures is often more effective than radiographs.

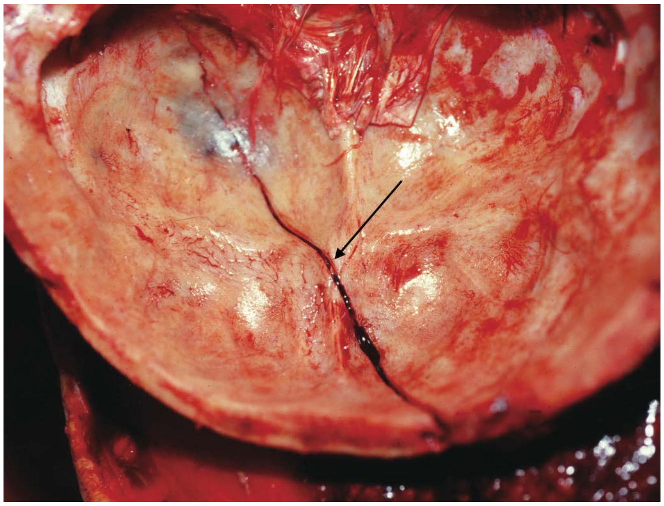


Figure 9.15 Fracture of the skull, occipital bone. The dura has been pulled from the base of the skull, revealing a fracture. This victim slipped, fell backward, and struck the head, suffering this fracture, subdural hemorrhage, brain swelling, and then death.

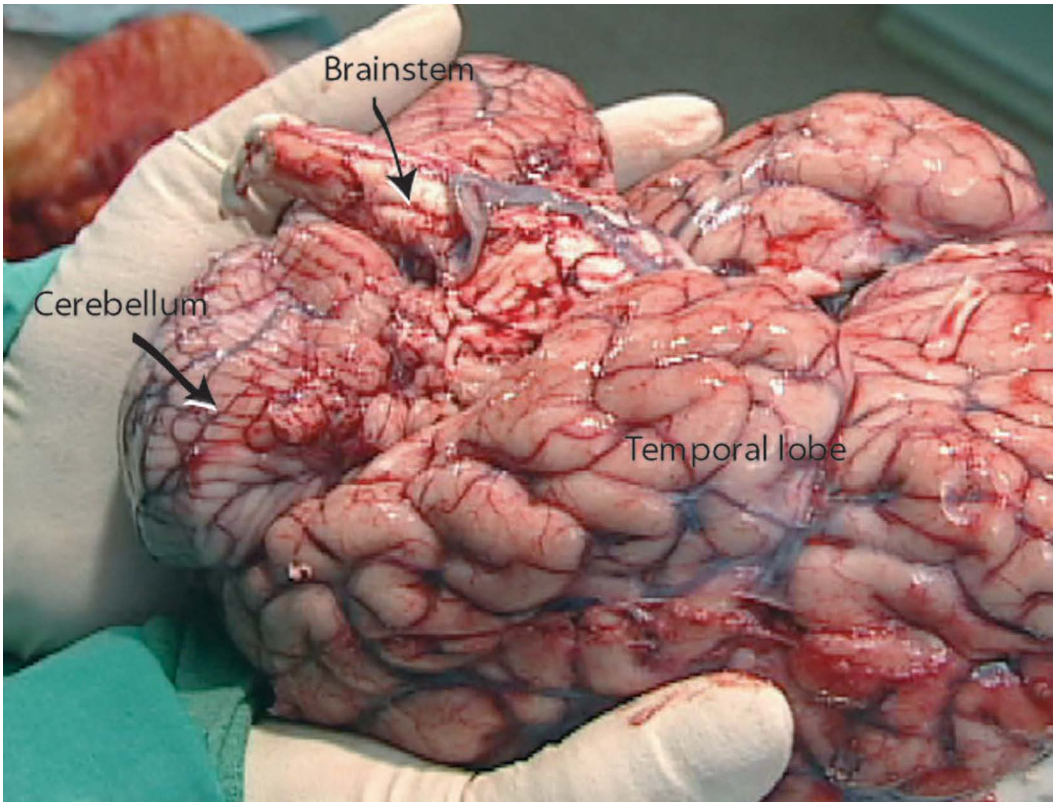


Figure 9.16 Brain upon removal. The exterior of the brain is examined, and the brain is weighed. Brain weight is generally 1.4% of body weight, or approximately 1100 g (2.4 lb) in a 77-kg (170-lb) person.

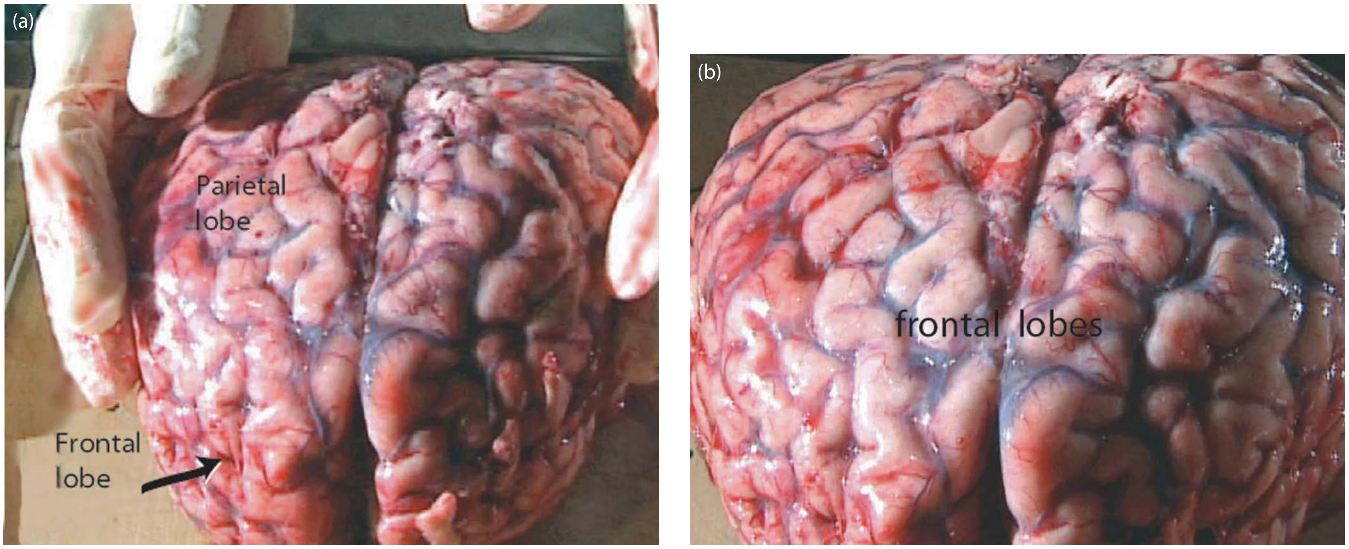


Figure 9.17 (a and b) Frontal and parietal lobes of the brain. This view of the convexity of the brain shows the many convolutions of the cortex. The peaks are known as gyri and the grooves are sulci. Note the many blood vessels; the brain is very vascular.

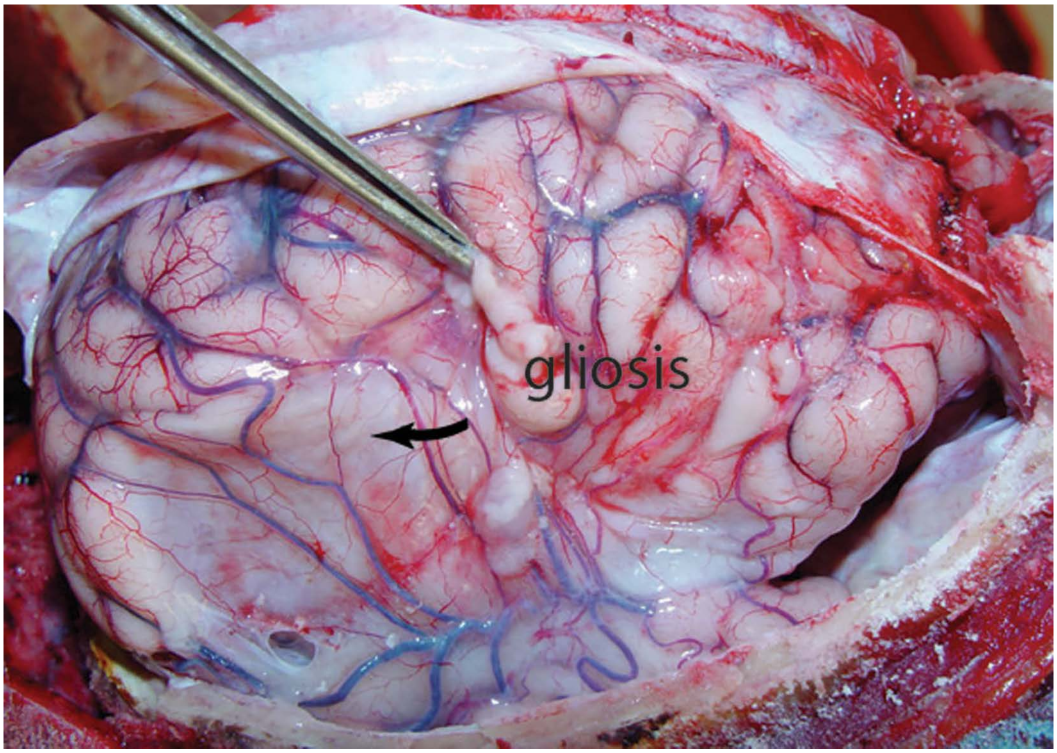


Figure 9.18 Gliosis. Injuries of the brain, such as scars or strokes, form a scarring called gliosis. The cortex of this brain is collapsed due to previous injury from a stroke.

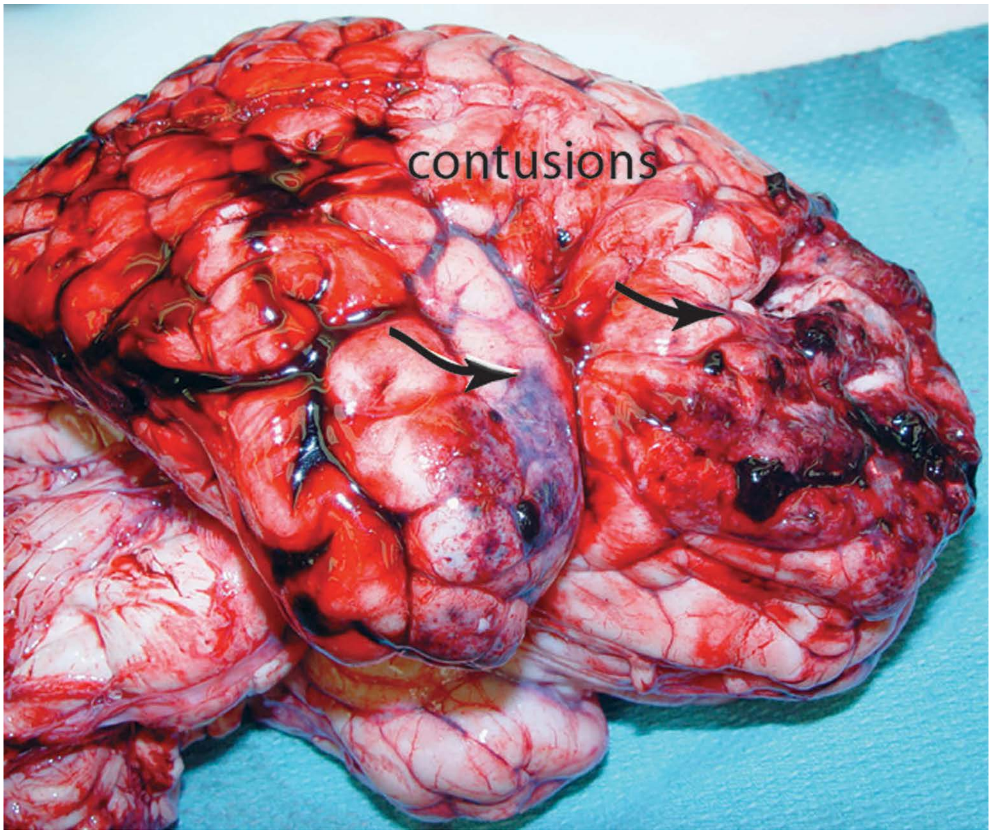


Figure 9.19 Contusions of the brain. The dark hemorrhagic areas of the brain display severe contusion from a motor vehicle crash. This contusion caused severe, fatal brain edema.

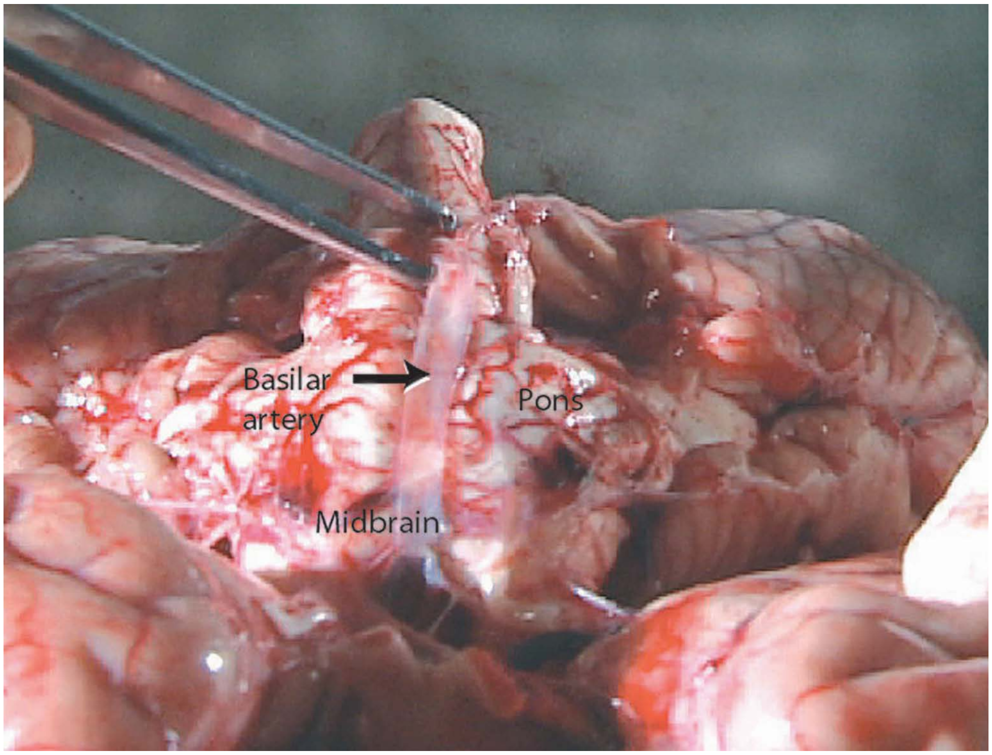


Figure 9.20 Vertebral basilar arteries at the brainstem. The arteries at the base of the brain are examined for atherosclerosis and anomalies. Significant blockage of these arteries can cause an infarction of the brain, known as a stroke. Aneurysms, or outpouchings, of the wall (saccular or berry aneurysms) can rupture, causing serious, commonly fatal, hemorrhage.

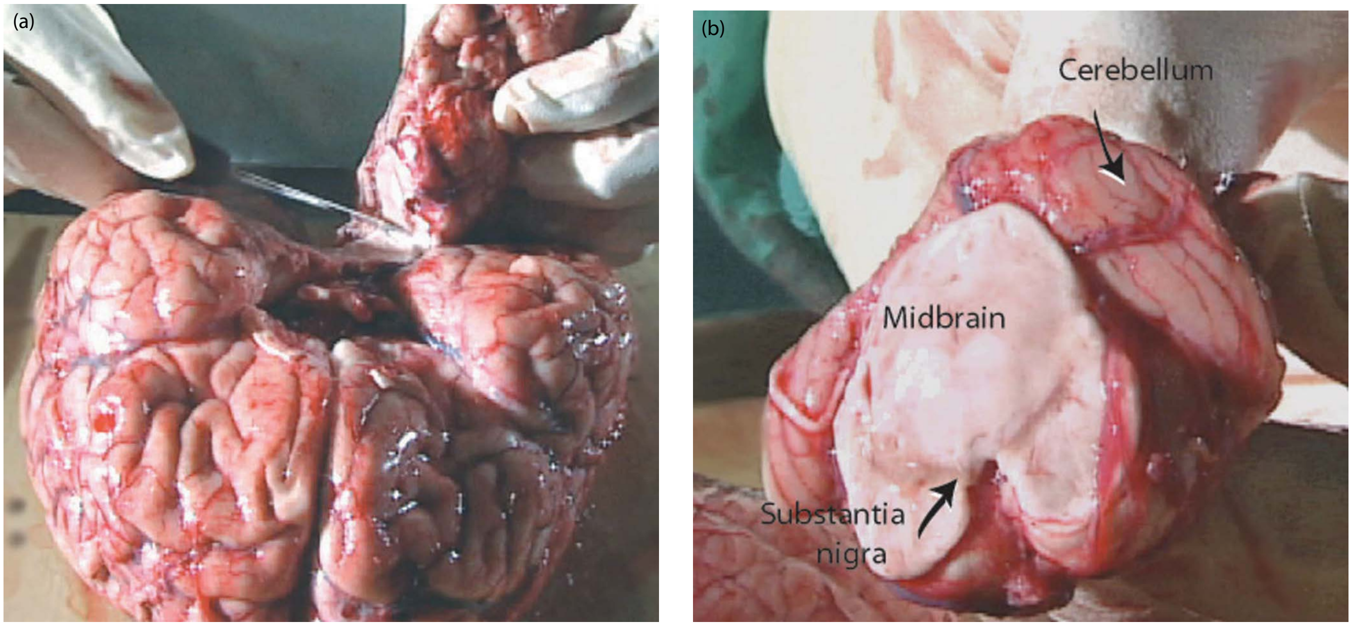


Figure 9.21 Examination of the midbrain. (a) The midbrain, brainstem, and cerebellum are removed. **(b)** This is a section of normal-appearing midbrain. Many vital functions are associated with this area.

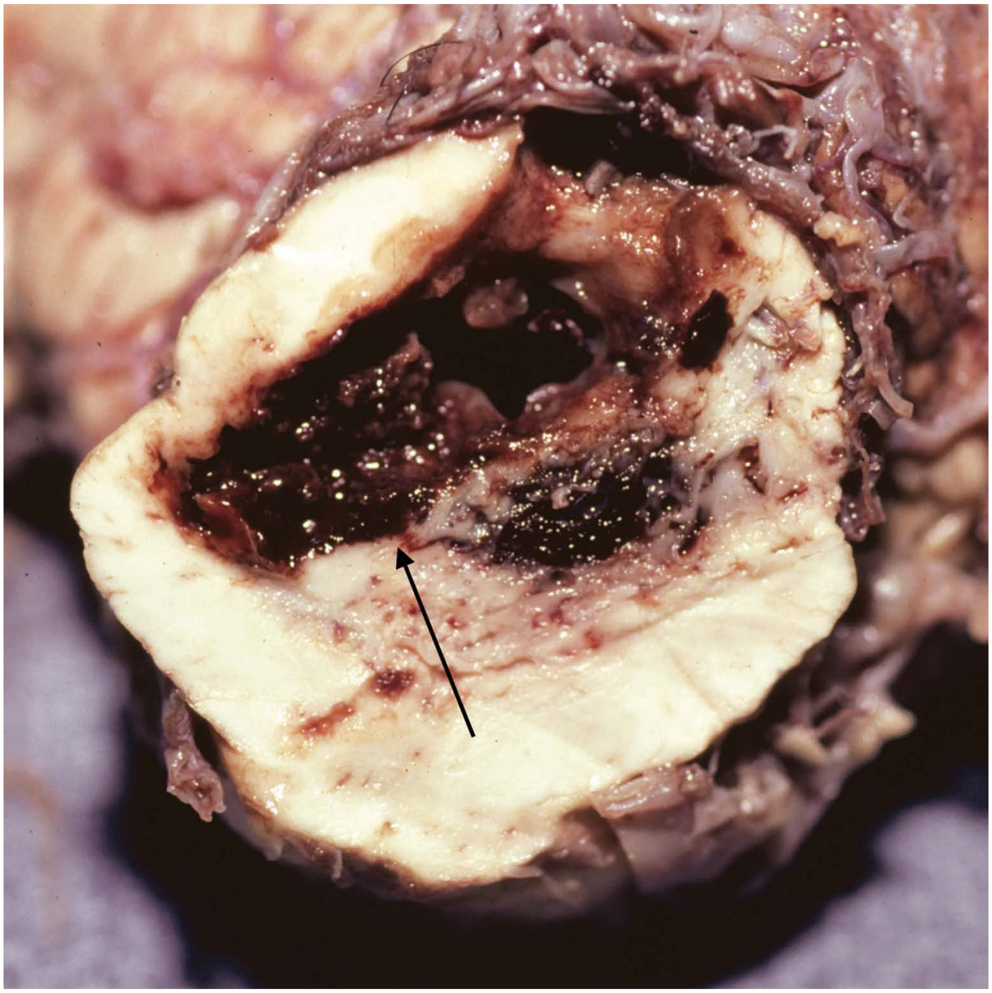


Figure 9.22 Brainstem with hemorrhage. Hemorrhage in the midbrain, as seen here, is almost always quickly fatal.

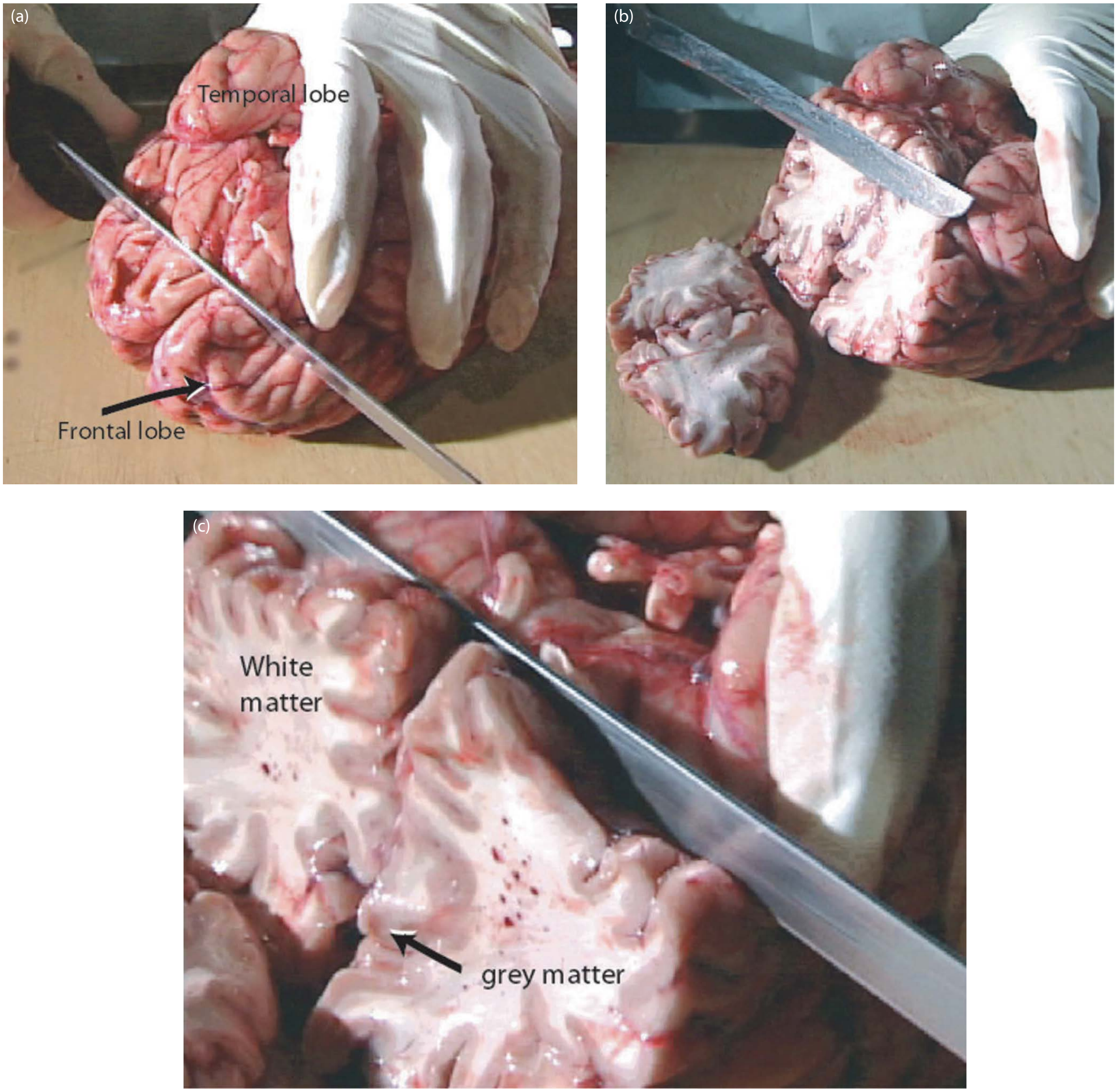


Figure 9.23 (a–c) Serial cutting of the brain. There are various methods for cutting the brain. One common method is cutting the brain perpendicular to the long axis, as shown here. The brain can be cut in the fresh state or, preferably, after fixation for approximately 1 month in formaldehyde. Hemorrhage and tumors are common findings.

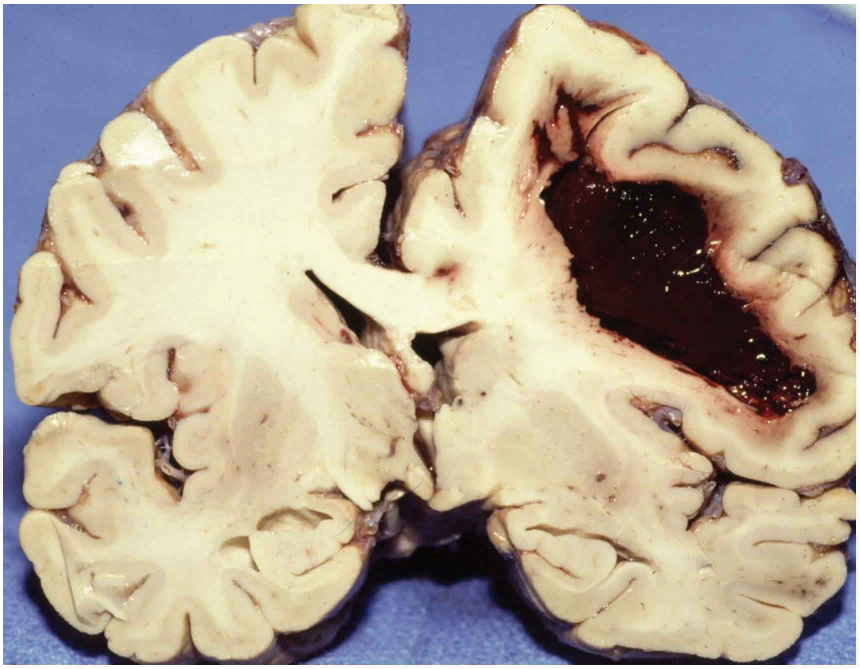


Figure 9.24 Cerebral infarct. This section of brain shows hemorrhage in the white matter. This patient had a history of hypertension.

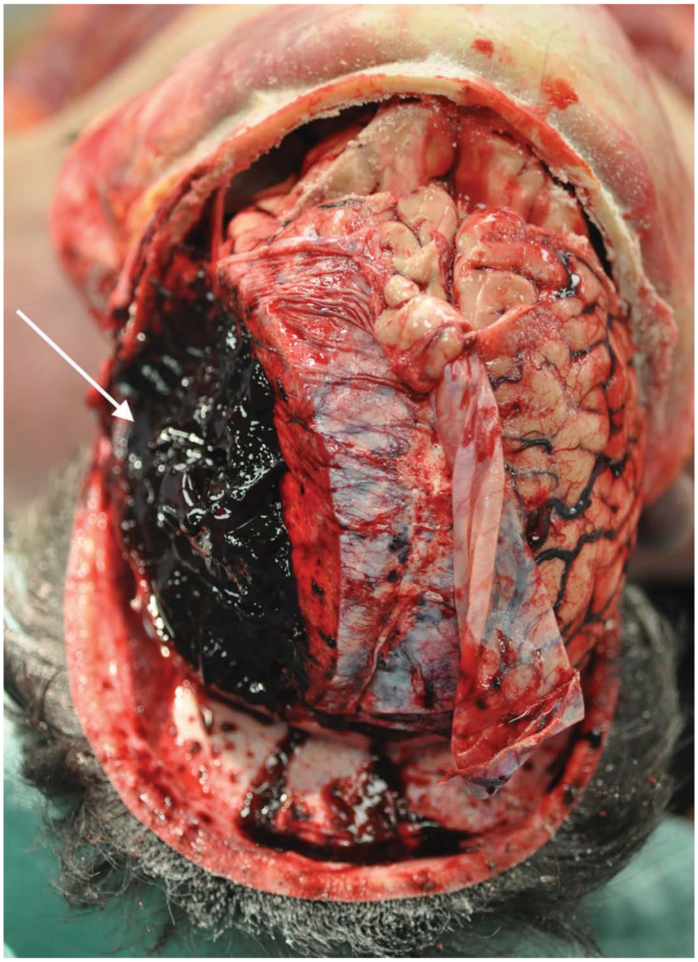


Figure 9.25 Epidural hematoma. Note that the hematoma is above the arachnoid and layer and dura mater layer, causing a shift in the brain away from the clot. Epidural hematomas are usually seen with a skull fracture, and therefore are not a natural disease process.

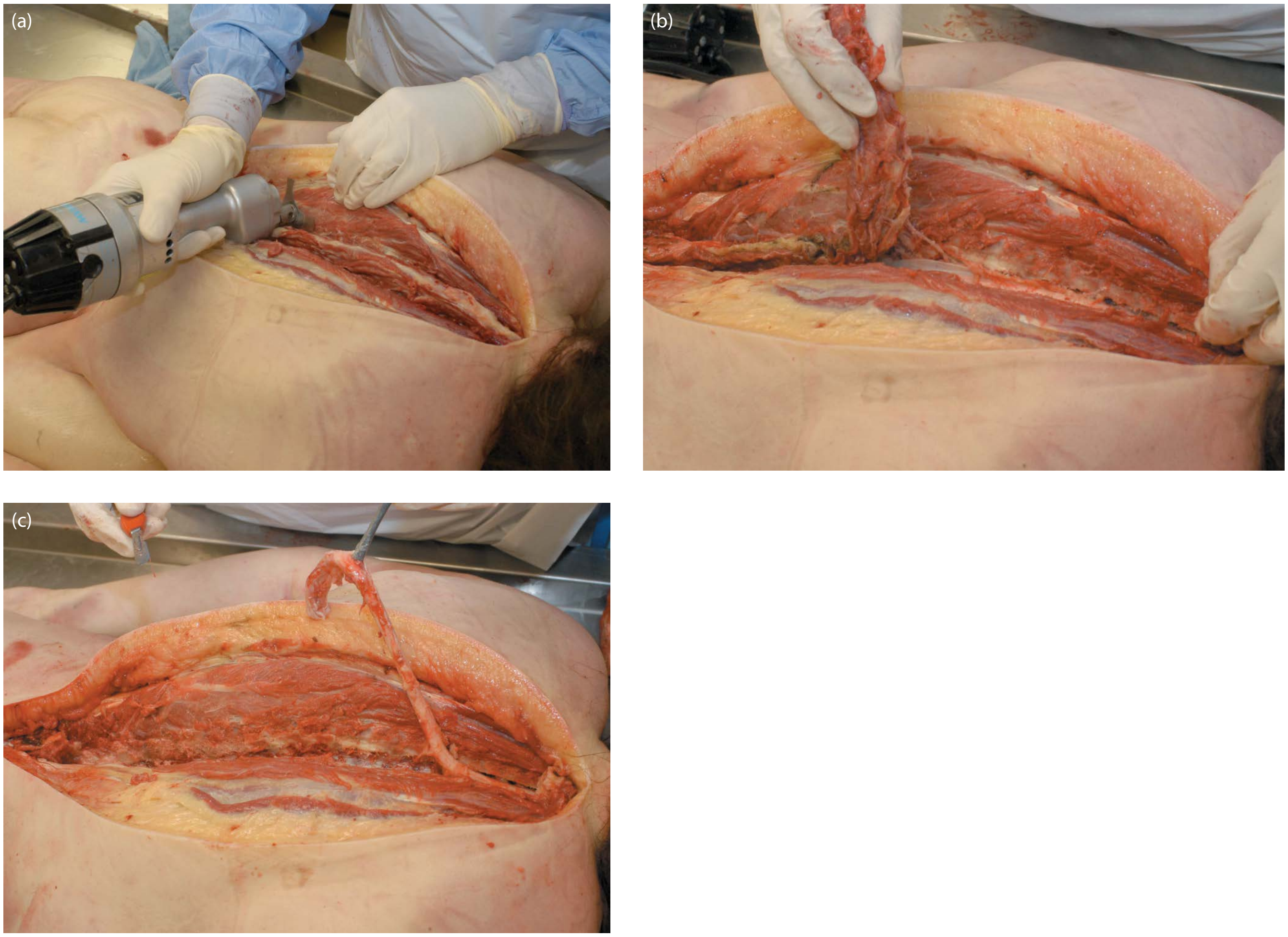


Figure 9.26 (a–c) Spinal cord examination. When spinal cord pathology or injuries are suspected, the cord is removed. The posterior method is depicted here. After exposing the spinal cord, the vertebral arches are cut up and down the spine, revealing the spinal cord below. The spinal cord is carefully removed. After removal of the spinal cord, the area is sewn together and sealed.

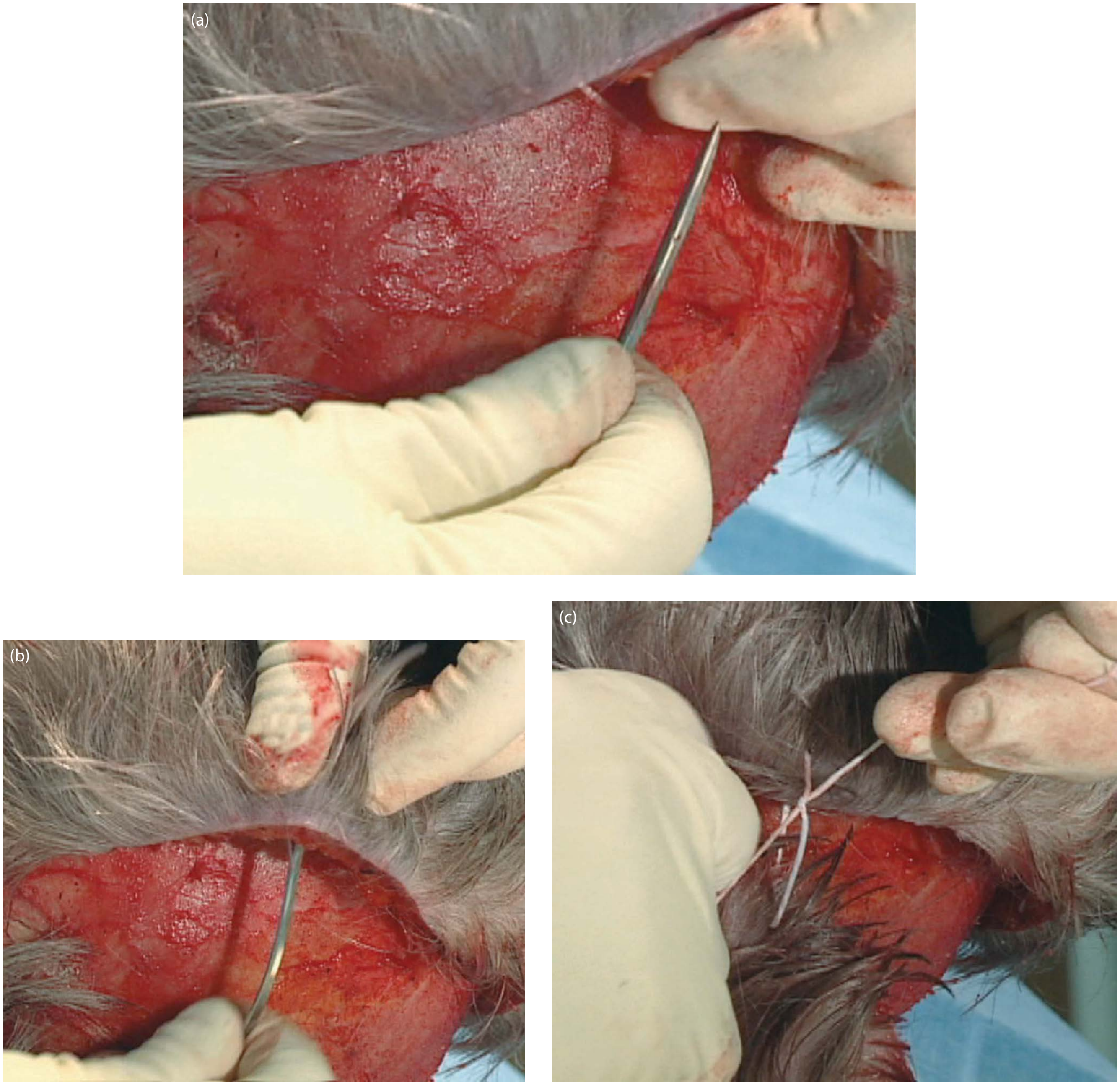


Figure 9.27 (a–c) Stitching the scalp. The skull is held together by stitching the scalp. The funeral director will tightly affix or glue the skull together. The incision will be hidden from view at the funeral.

CHAPTER 10
MICROSCOPIC EXAMINATION

Making diagnoses using the microscope is the trade of most pathologists. If one has a breast biopsy or a tumor removed, the pathologist classifies the tumor and diagnoses the lesion as benign or malignant. The skill of making microscopic diagnoses is very useful in postmortem examinations because the microscopic examination is used to support and supplement the gross findings in an autopsy.

The gross examination portion of the autopsy usually yields the cause and manner of death; that is, the pathologist normally walks away from the autopsy suite with a good idea of the major diagnoses and the cause and manner of death. For example, the pathologist does not need to look at microscopic slides to diagnose a contact gunshot wound of the head. However, he or she will take sections of the wound to confirm microscopically that there is heavy soot deposition in the wound. As such, the microscopic examination serves, in most cases, to supplement the autopsy.

In some cases, microscopic examination is pivotal in making a major diagnosis and in determining the cause and manner of death. These diagnoses include:

- Malignant tumors—lung, liver, colon, and breast carcinomas; lymphomas
- Heart—myocarditis versus myocardial infarction
- Lung—pneumonia versus congestion, which are often difficult to differentiate grossly
- Liver—chronic hepatitis and metastatic carcinomas
- Spleen—splenitis, one sign of sepsis
- Kidneys—nephritides, leading to renal failure (e.g., lupus)
- Infections—any tissue or organ; meningitis or inflammation of the coverings of the brain

Figures 10.1 through 10.23 are sample diagnoses of conditions and injuries that can be made by microscopic examination. These figures demonstrate how a pathologist uses the microscope to support, prove, or determine the cause or manner of death.

Figure 10.1 The microscope, the tool of the pathologist. Whether it is used to diagnose tumors or to study abnormal tissues seen grossly at autopsy, the microscope is the "stethoscope of the pathologist." Many findings cannot be diagnosed with the gross autopsy, and a few of these are seen in the following figures.

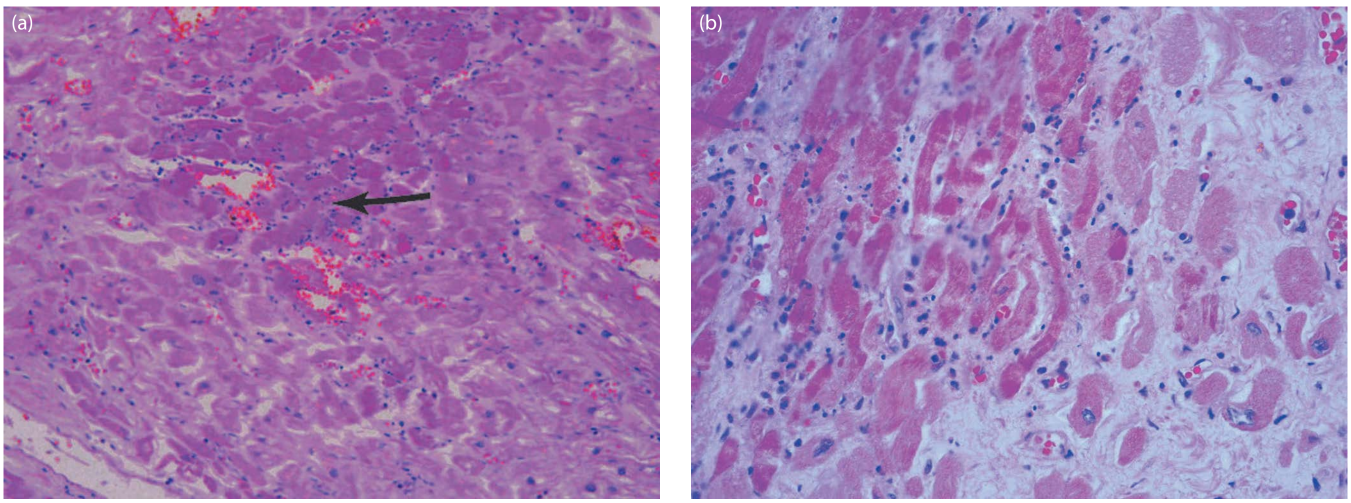


Figure 10.2 Acute myocardial infarction. (a) The arrow points to red, dead cardiac muscle cells. This cell death results from lack of blood flow (ischemia), as blood carries oxygen and other essential nutrients to the cells. The death of the cells invokes an inflammatory response. The small blue dots in the figure around the arrow are neutrophils, the sentinels of the acute inflammatory response. **(b)** This higher magnification shows the red serpentine fibers and the surrounding blue inflammatory cells.

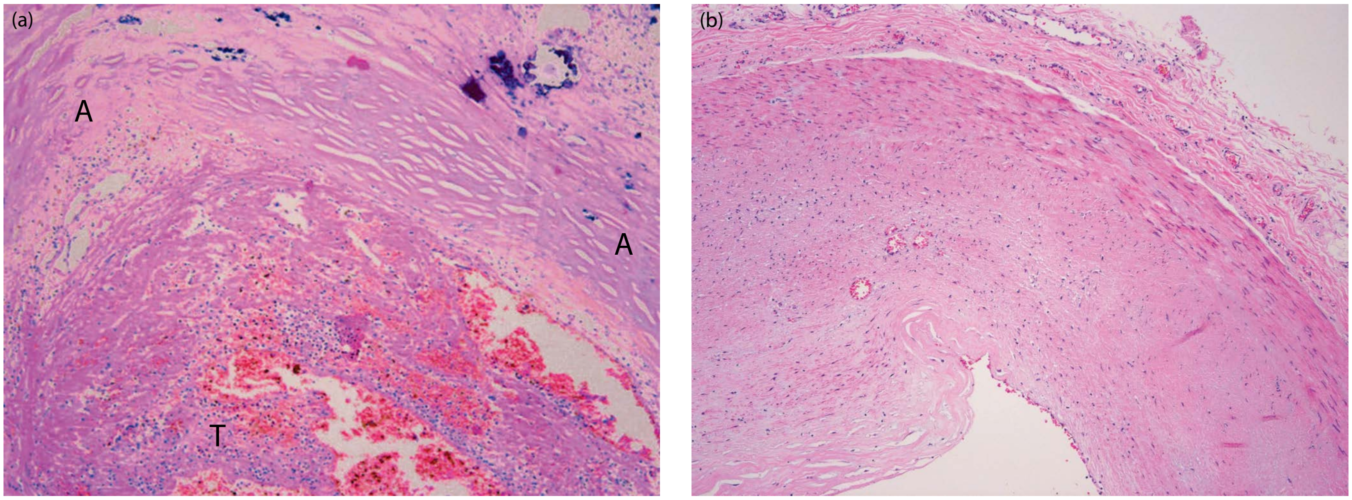


Figure 10.3 (a) Thrombosed (clotted) coronary. "A" is the arterial wall; "T" is the thrombus. The supply of blood to the cardiac muscle cells is carried out by the coronary arteries. Most commonly, as these arteries become clogged with atherosclerotic plaque or thrombi (clots), the myocardium dies, producing a myocardial infarction. **(b) Normal coronary.** The normal, open coronary artery is compared to the thrombosed artery.

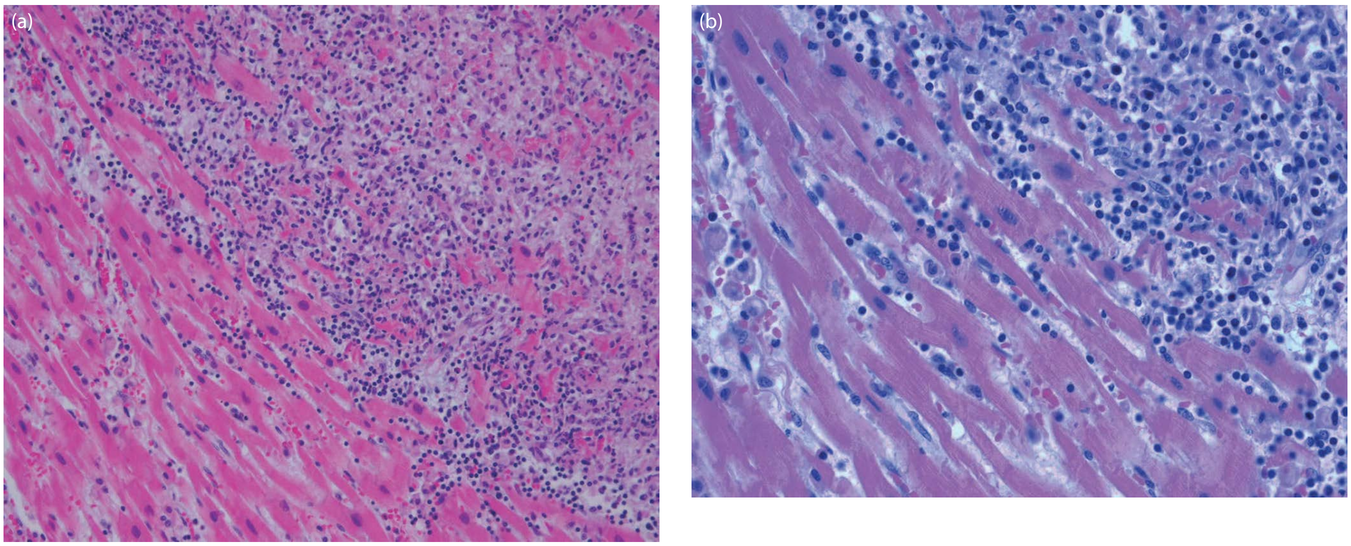


Figure 10.4 (a and b) Myocarditis. These images are microscopic examinations of the gross photographs shown in Figure 8.19a and 8.19b. The pink-red myocardial fibers on the left are invaded by a diffuse lymphocytic and monocytic inflammatory response. Lymphocytes and monocytes indicate chronic inflammation. This type of inflammation most likely represents a viral origin of this myocarditis.

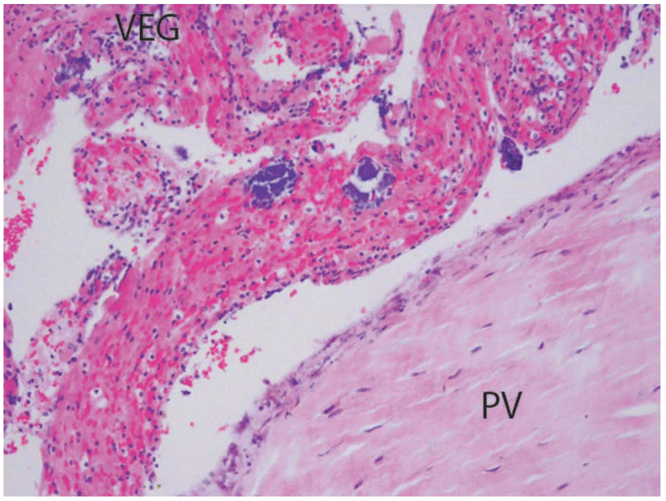


Figure 10.5 Vegetations of the pulmonic valve. "PV" is the pulmonic valve; "VEG" is vegetation. Damaged or malformed valves can collect bacteria and thrombi (clots). These bacteria-laden clots can travel to the lung, causing infection and infarction (septic emboli); in the case of the mitral and aortic valves, they can travel to the brain, kidneys, and fingernails (also see Figure 5.15c and 5.15d).

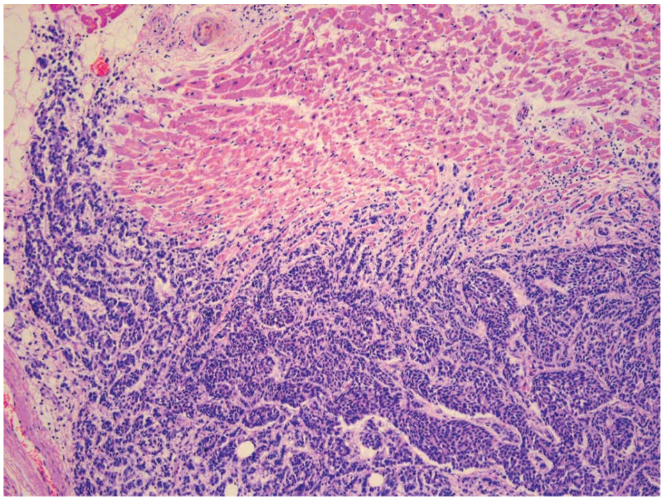


Figure 10.6 Carcinoma invading the heart. This patient had metastatic (spread outside the primary carcinoma) lung carcinoma. The carcinoma invaded the pericardium and then the heart (also see Figure 6.23).

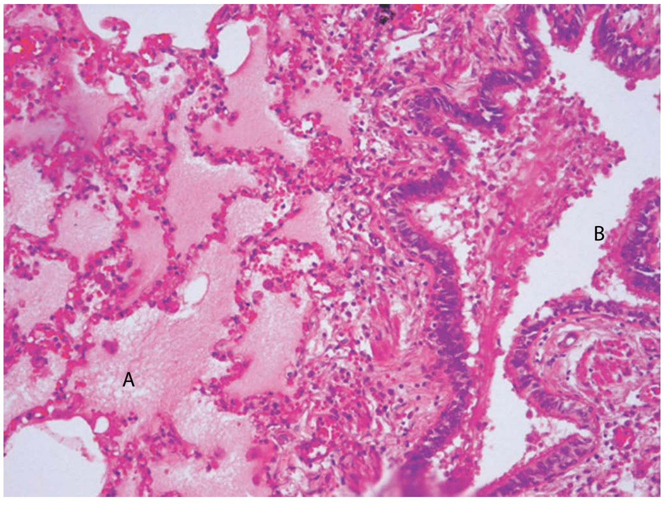


Figure 10.7 Pulmonary edema. "A" is alveolus; "B" is bronchus. Pink pulmonary edema is fluid in the airways, alveolus, and bronchus. This fluid comes from the rich vascular network in the lungs. If the heart does not pump properly or an excess of certain drugs is present (e.g., narcotics), fluid leaves these blood vessels and goes into the alveolar air space (also see Figure 8.43). There are many other causes of pulmonary edema (see the references for a detailed discussion).

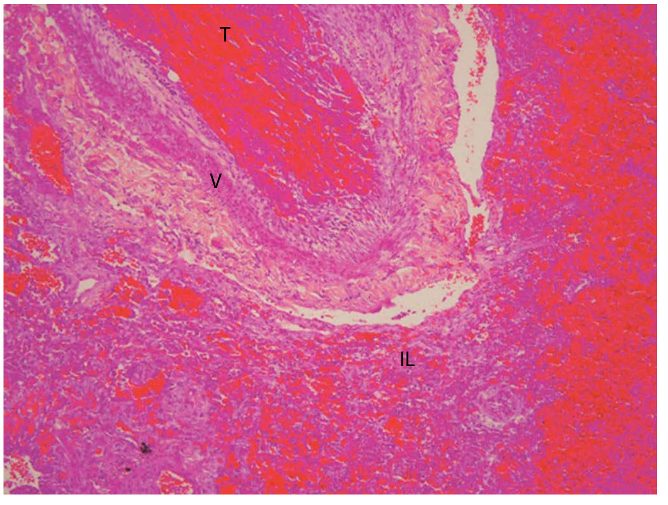


Figure 10.8 Pulmonary embolus with infarction. "T" is thrombus; "V" is pulmonary artery; "IL" is infarcted lung. As with the heart, a clot stopping the blood flow causes infarction. In the lung, however, there is a dual blood supply: the bronchial arteries. Blood from these arteries pumps in, causing the bright red hemorrhage seen in the figure, called a hemorrhagic infarction.

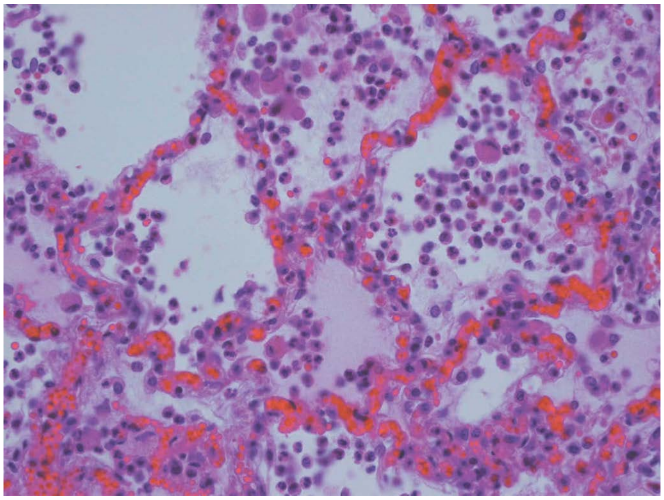


Figure 10.9 Lobar pneumonia. The alveolar spaces are filled with numerous inflammatory cells and other debris. This inflammatory material is usually the result of bacterial infection, and one can see how, in the alveolus, it can interfere with air exchange in the lung.

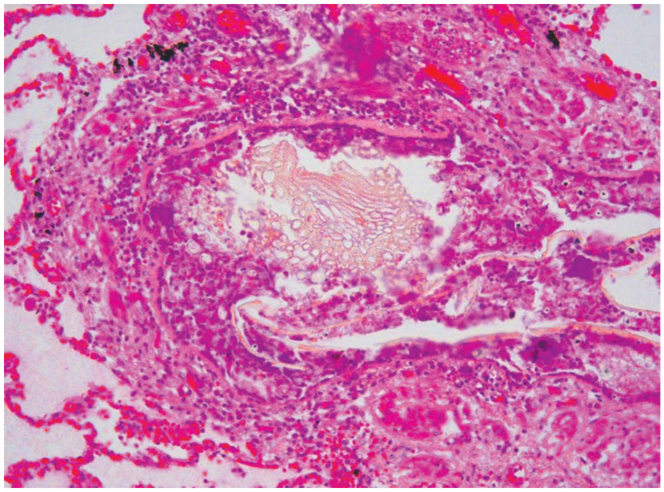


Figure 10.11 Plant matter in a bronchus. This unfortunate victim fell into a grain elevator. Grain is loose enough for a man to sink down into, as in quicksand. The grain surrounds the body eventually, not allowing the person to raise the chest wall to breathe. This victim was buried deep into the mountain of grain. At the same time, grain was inhaled into the mouth, causing aspiration into the lung.

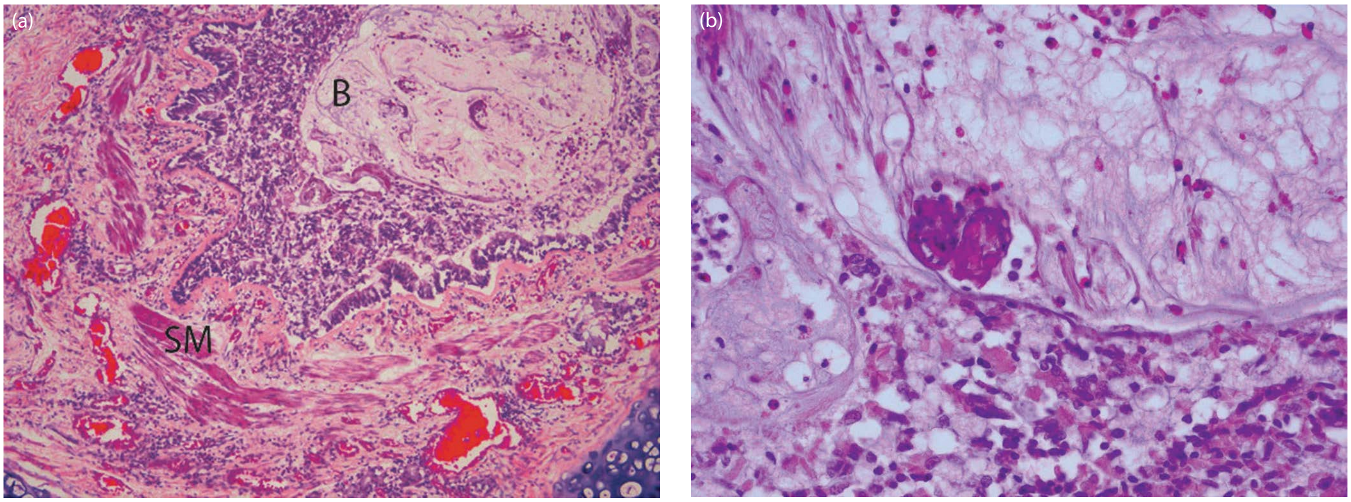


Figure 10.10 Asthmatic lung. (a) "SM" is smooth muscle; "B" is bronchus. In asthma, the airways are over-reactive in reacting to allergens, for example. The bronchi, surrounded by smooth muscle, clamp down, decreasing air flow. Increased mucus is secreted, and the eosinophils are prominent. The result is wheezing, difficulty breathing, and, in status asthmaticus, possible respiratory failure and death. The image shows hypertrophied smooth muscle and mucous plugging in a patient who died of status asthmaticus. **(b)** Note the numerous red eosinophils, mucus, and a central red conglomerate of shed epithelial cells called Curschmann's spirals, an occasional microscopic finding in asthma.

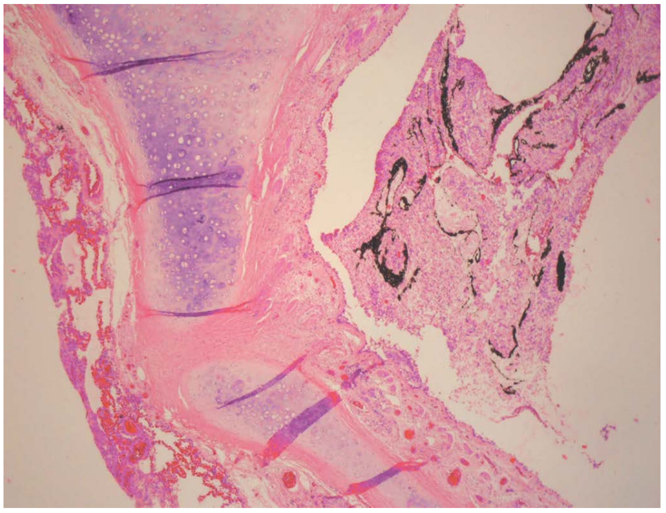


Figure 10.12 Soot in the trachea. In fire deaths, a great deal of soot (and hot air) can be inhaled. The image shows black soot and mucus on the right. The trachea is seen on the left.

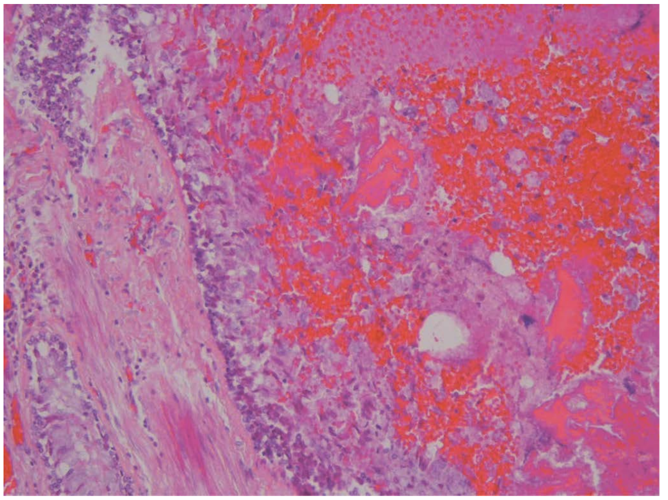


Figure 10.13 Aspirated blood. Many traumatic injuries of the head, face, mouth, and neck can cause blood to run into the bronchi. The blood can interfere with respiration and cause or contribute to asphyxia. Blood can be seen on the right side of this image.

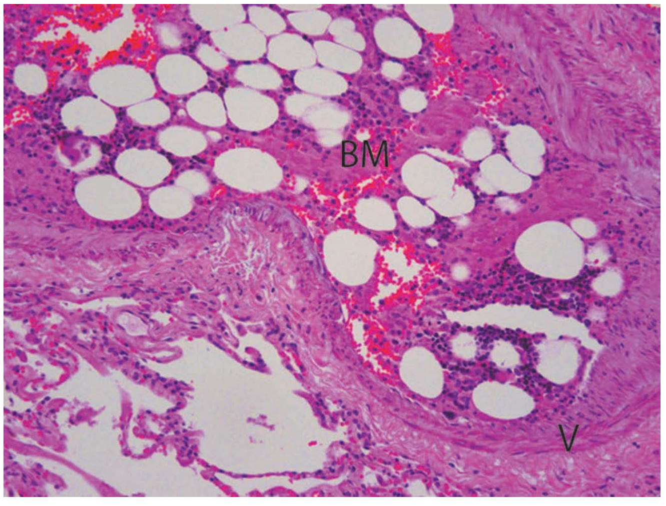


Figure 10.14 Bone marrow embolus in the lung. "BM" is bone marrow; "V" is blood vessel. Even properly performed cardiopulmonary resuscitation can break ribs, but only in adults (see Figure 6.5). At times, breaking of the ribs results in small bone fragments entering the bloodstream and, as in this case, stopping in the lungs. Fractures of large bones can also cause this phenomenon.

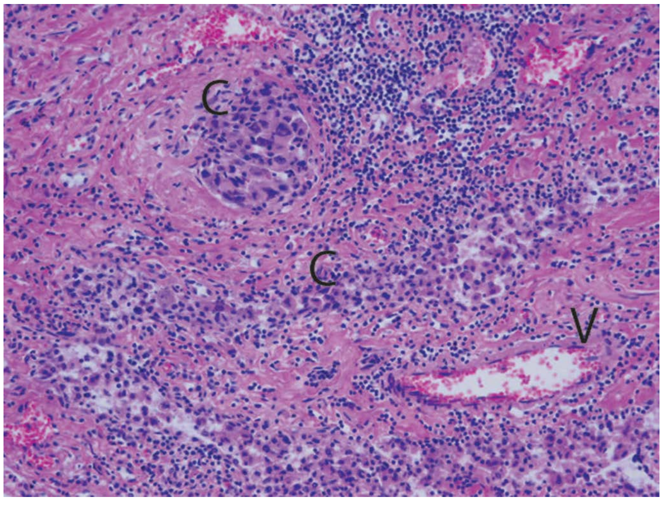


Figure 10.15 Invasive carcinoma of the lung. "C" is carcinoma; "V" is blood vessel. Any carcinoma, like this carcinoma of the lung, attacks the body by invading local and distant tissues. Carcinoma also invades the blood and lymph systems, as can be seen here. The large, malignant cells are highly and abnormally active, multiplying at an extreme rate and taking nutrients from the normal tissues.

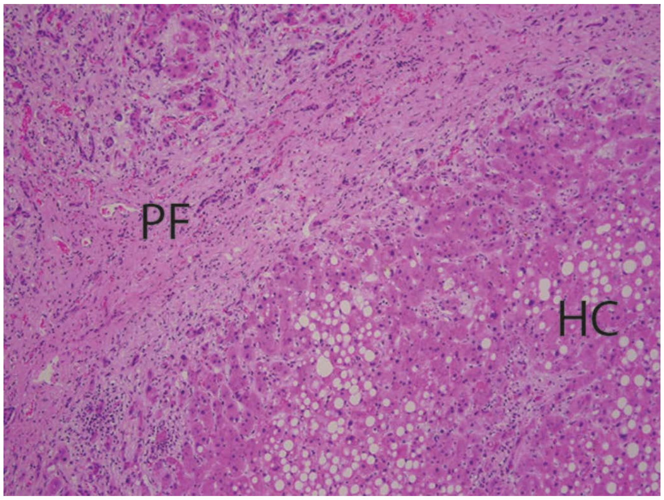


Figure 10.16 Cirrhosis of the liver. "PF" is portal fibrosis; "HC" is hepatocytes (liver cells). Cirrhosis is a reaction to damage to the liver. The damage can come from a virus (hepatitis), a toxic substance (ethyl alcohol), or a poison (carbon tetrachloride), among other causes. The resulting scarring or fibrosis bridges the portal areas. The end result of cirrhosis is liver failure. Clotting factors are not made; therefore, the patient is prone to bleeding. In addition, since the fibrosis interferes with portal blood flow, the veins around the esophagus and anus dilate and are prone to rupture.

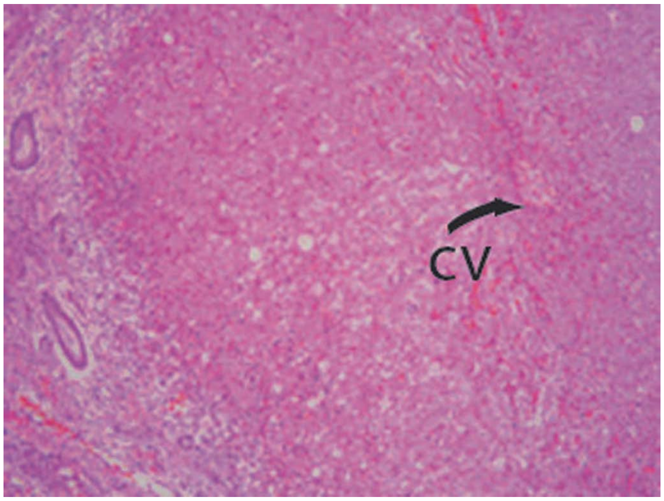


Figure 10.17 Central venous necrosis of the liver (shock liver). "CV" is central vein. Prolonged shock can cause the part of the liver with less blood flow (central vein region) to die (necrotize). The right part of this image demonstrates such necrosis, which causes liver failure.

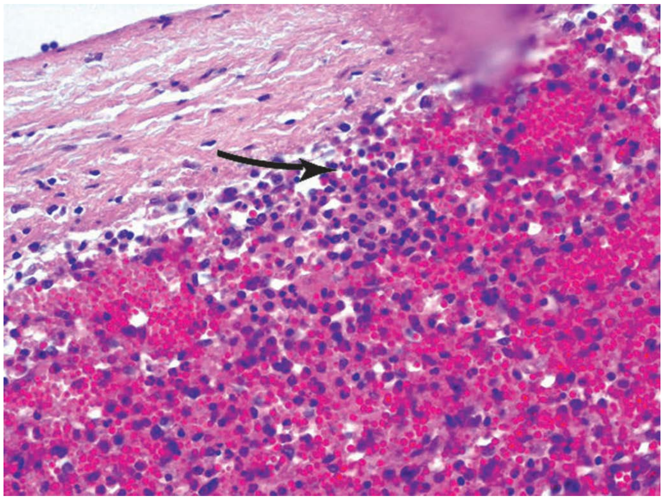


Figure 10.18 Splenitis. Neutrophils can be seen near the capsule (arrow) of the spleen in this patient who died of sepsis. The red pulp is congested as well. Postmortem blood cultures and knowledge of premortem history of sepsis are the best ways to diagnose this condition. Occasionally, splenitis is seen in sepsis.

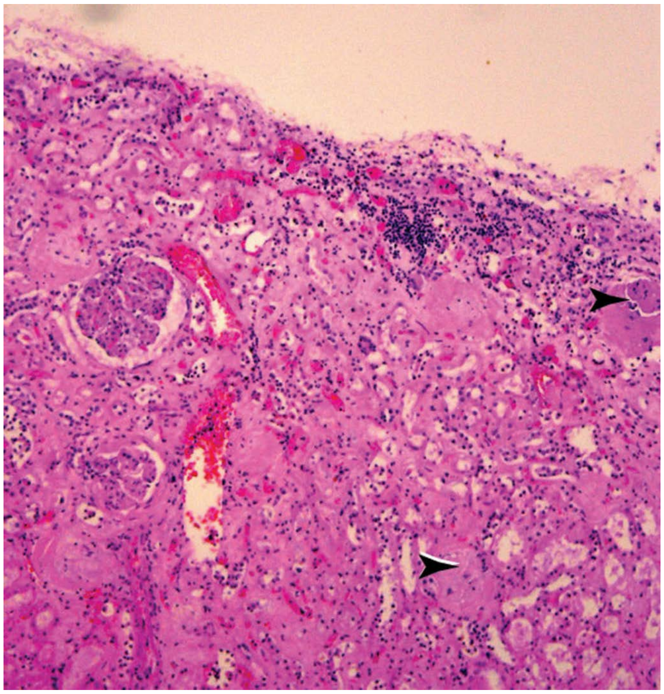


Figure 10.19 Renal arteriolosclerosis. The smooth outer cortex of the kidney is gone here. Hypertension has damaged the blood vessels supplying the glomerulus, causing sclerosis of the glomeruli (arrowheads) and surrounding tubules and resulting in a pitting of the surface of the kidney (see Figure 8.71).

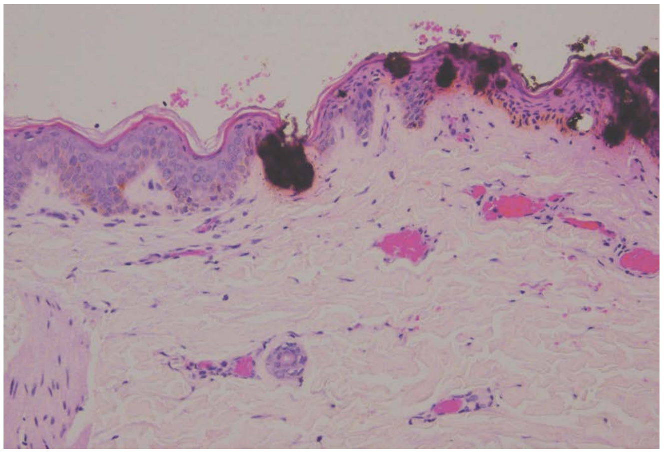


Figure 10.20 Soot deposited in the skin from a contact gunshot wound. Soot can be seen in the epidermis on the right side of this image. The soot tattooed the skin because the barrel was close enough for the soot to be deposited. This microscopic section helps to substantiate the gross finding of soot on the skin in a gunshot wound (see Figure 2.1).

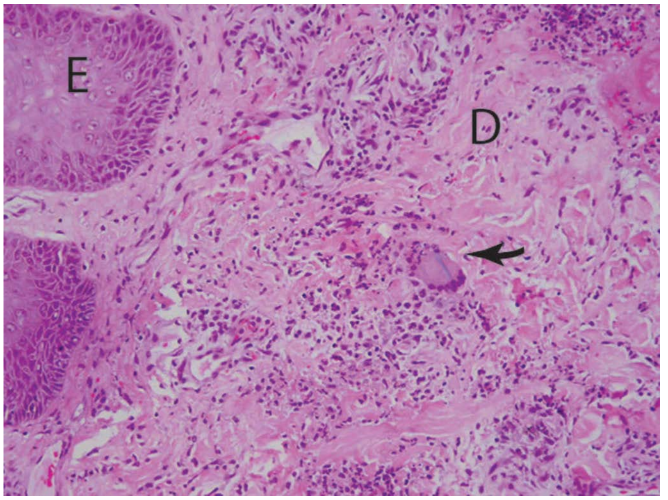


Figure 10.21 Skin granuloma in intravenous (IV) drug abuse. "E" is epidermis; "D" is dermis. The chronic injection of the skin with drugs and their impurities, like talc or baby powder, forms a granulomatous reaction of the skin (arrow). A bluish needle-like foreign object can be seen within the granuloma. This section helps to document the history of IV drug abuse. These granulomas can also be seen in the lungs (see Figure 3.46a and 3.46b).

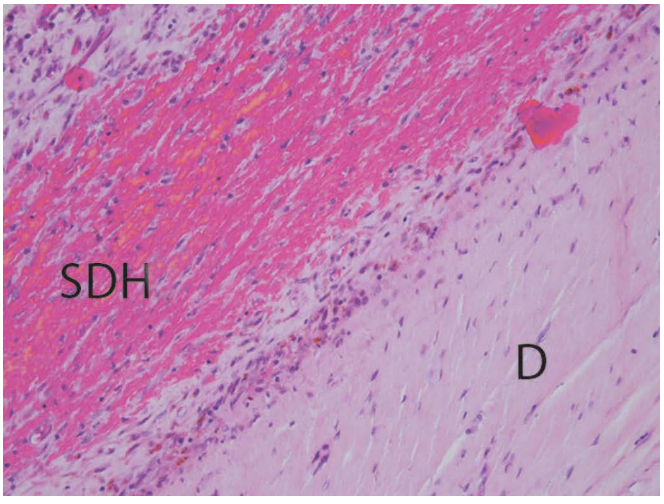


Figure 10.22 Chronic subdural hematoma. "D" is dura matter; "SDH" is subdural hematoma. A microscopic examination can give an idea of the age of injuries. This dating is not absolute. For example, this image shows organized hemorrhage; therefore, the hemorrhage is at least 3 weeks old (i.e., it is not acute).

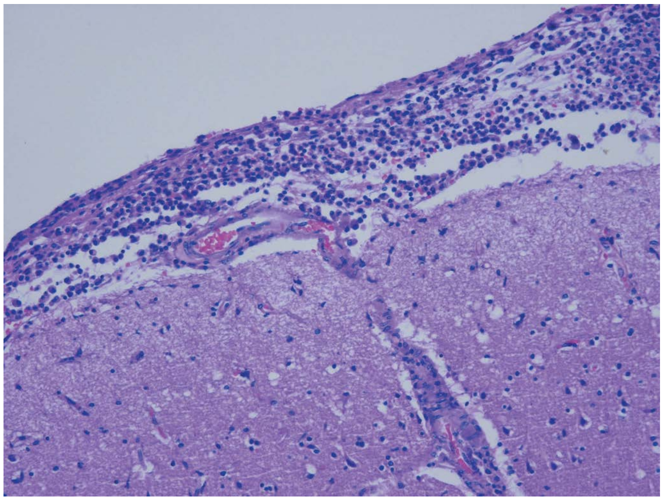


Figure 10.23 Meningitis. Meningitis is the inflammation of the meninges covering the brain. It can be caused by bacteria, viruses, fungi, or other sources. The result is the dark blue strip of inflammatory cells seen at the top of the image. The specific organism that causes meningitis is best determined by microbiologic culture.

CHAPTER 11

POSTMORTEM LABORATORY ANALYSIS OF DRUGS, CHEMICALS, AND MICROORGANISMS

The postmortem laboratory analysis of body fluids and tissues is an essential tool for the forensic pathologist. Toxicology studies are useful for helping determine the cause and manner of death and for answering key investigative questions. This book has shown the power of visual gross and microscopic findings in the autopsy. Drugs and chemicals, however, seldom leave characteristic or identifying visual findings at the autopsy. Even those substances that do leave visual findings, such as cyanide (causing pink livor mortis) and carbon monoxide (causing red livor mortis), must be confirmed and quantified. The specific drugs or chemicals that are found and their concentrations tell us a story about the death. The discovery of unexpected poisons can identify a perpetrator or even save a life. For example, finding a blood carbon monoxide of 50% in a person who died at home during the winter might save the lives of the other occupants by implicating a faulty furnace.

The pervasive use and abuse of alcohol, cocaine, marijuana, amphetamines, heroin, and even prescription drugs in today's society necessitate determining whether these chemicals had any bearing on a death. The presence of these compounds is especially important if the death occurred on the job or as a result of a vehicle crash. Toxins and poisons in the environment, the home, and the workplace are increasingly common. The Occupational Safety and Health Administration investigates deaths involving toxins or poisons in the workplace. The Federal Aviation Administration and the National Transportation Safety Board require toxicology studies in many death investigations, such as those of pilots who died in airplane crashes.

Drug and alcohol analysis is part of a complete death investigation. To perform this analysis, the investigator, pathologist, and toxicologist must work together. The toxicologist heads up this team. Standard blood and urine screens are performed for commonly abused drugs and alcohol. These toxicology tests do not test for every possible drug or poison. If any drugs outside of the standard toxicology screen are suspected, the toxicologist must be informed, since the method of analysis can depend on the compound suspected. In short, the investigator should say more to the toxicologist than simply, "Look for poison."

THE SCENE AND THE BODY

The search for drugs and poisons begins at the death scene. Prescription drugs should be logged and the number of pills in each container should be counted. One should be sure that the drug in the container is the same as that named on the label. Potentially fatal problems can arise when patients under therapeutic drug treatment as prescribed by a physician take either less or more medication than prescribed. In accidental and suicidal overdoses, the number of pills present can be much lower than it should be based on the last refill date. Patients with seizure disorders, for example, can succumb to *status epilepticus* (prolonged, violent seizure leading to respiratory arrest) if they stop taking their prescribed seizure medication. As pointed out in Chapter 2 (p. 10), the types of medication that are present speak to the medical history. The medication bottles list the prescribing physician, who is a good source of further information about the victim. Pertinent hospital, clinic, and doctors' office records should be reviewed.

Alcohol is the most common drug found in medical examiners' cases. Searching the death scene for empty alcohol containers and counting these containers is the first step. In addition to searching for illicit drugs, the trappings of drug abuse (Figure 11.1), such as paraphernalia, whether the deceased was found in a known "drug house," and other observations, should be noted. Often drugs, needles, and similar items can be found around or even on the body (Figure 11.2a and 11.2b). In illicit drug deaths, witnesses commonly remove or dispose of the drugs. Searching arrest records can help uncover drug abuse history. Drug-oriented tattoos (Figure 11.3), clothing, and other materials can also alert the investigation team. Families are a good source of information regarding a drug abuse history, as they seem to open up after the death and say what they know.

A well-publicized method of suicide involves tying a plastic bag over the head and taking a large amount of propoxyphene, codeine, or other pain medication. These deaths can be recognized by the fact the bag is tied shut, presumably having been tied by the deceased (Figure 11.4). The mechanism of death in these cases is asphyxia due to the lack of oxygen in the bag, aided by the drugs acting as respiratory depressants.

Another, sometimes fatal, practice involves inhaling substances while placing one's head in a plastic bag. Figure 11.5a shows an adolescent who inhaled nitrous oxide from canisters, or "whippets," while his head was in a plastic bag (Figure 11.5b and 11.5c). The bag became a low-oxygen environment when the decedent attempted to breathe. This method concentrates the nitrous oxide gas, giving a better "high." As the nitrous oxide was released, it replaced the oxygen in the environment even further, resulting in asphyxia from low oxygen. Note the belt used to cinch the bag closed.

The nose and mouth should be examined for drug residues. Crack cocaine smokers can have darker than usual oral mucosa. Glue sniffers or aerosol "huffers" can have residue around the mouth and nose. The hands and extremities should also be examined. Figure 11.6a shows the hand of an adolescent who was suspected of sniffing glue. A search of the house uncovered a glue container (Figure 11.6b), the color of which matched the residue on the hand. The antecubital fossa, legs, and feet should also be searched for intravenous drug abuse needle marks or scars (see Figure 3.46a and 3.46b).

Some poisons and drugs have unique odors. Cyanide, for example, smells of bitter almonds. The sickly, fruity smell of ethyl alcohol at autopsy is characteristic. However, one must be cautious when interpreting the odor of alcohol. The author has found that the strength of the odor does not necessarily correlate with the blood level. In addition, other compounds such as acetone can smell like alcohol. In deaths due to diabetic ketoacidosis, acetone levels are elevated.

SPECIMENS TO OBTAIN AT AUTOPSY

Blood

Blood should be saved at all autopsies. Sodium fluoride tubes (or another preservative) should be used if the blood is to be saved for any period of time because they inhibit bacterial growth. At least 20 mL of blood should be obtained. Half of this blood should also be placed into plain tubes. Blood is the specimen of choice for alcohol analysis, providing the result as a percentage. For example, 0.08% is the legal limit for operating a motor vehicle in many states. Care must be taken not to use contaminated blood samples. When the stomach is ruptured from a motor vehicle crash, for example, the contents could be admixed with heart blood. When the specific level of a drug is needed, blood concentrations are measured. Drug concentrations can vary depending on the collection site. In addition to taking heart blood, femoral artery and/or subclavian samples should be taken. At least one tube should be saved for future testing. The legal defense team might want to have the specimen tested in another laboratory because new questions might arise over time.

Urine

Urine is the ideal specimen for drug screening. When a drug is detected during screening, the drug can be quantified in the blood. At least 10 mL should be saved, or ideally 30–60 mL. A common problem is that very little or no urine is present at autopsy. In such cases, bladder washings can be performed.

Vitreous Humor

Approximately 2–3 mL of clear vitreous fluid can be obtained from each eye and placed in a clean tube. Vitreous fluid is useful for confirming alcohol levels when contamination of blood is suspected. Drug analysis can also be done, and sodium, chloride, glucose, and blood urea nitrogen can be reasonably analyzed. Since vitreous glucose decreases after death, the analysis is helpful only in hyperglycemia.

Gastric Contents

The stomach is tied off at the duodenum and esophagus for removal. Approximately 50 mL of specimen is ideal. Any pills should be saved. Gastric analysis is very helpful for establishing intent in suicidal overdose cases.

Bile

Bile is useful in cocaine and narcotic analysis. These drugs are concentrated in the bile.

Tissues and Other Specimens

Liver, kidney, brain, heart, muscle, and fat can all be used in toxicologic analysis, especially when no liquid specimens are available. Many drugs are eliminated by the liver or kidneys; therefore, the drug can be found if it is present. These specimens are useful if the decedent has been embalmed or is decomposed, or if blood is not available. The type of specimen needed for each drug is variable and depends on the drug that is suspected and the route of introduction to the body. Consultation with a forensic toxicologist is very helpful before performing the autopsy so that the tissue and amount of specimen are optimal for the drug or toxin that is suspected.

Hair, nails (preferably toenails), bone, and even maggots can be used to detect drugs or poisons. These analyses are performed in order to detect the drug (qualitative analysis), not to determine the quantity of drug. Hair is the best specimen for detecting arsenic poisoning. In addition, hair samples can be used to detect chronic drug abuse.

Finally, all specimens are submitted to the toxicology laboratory with a chain of custody form. This form indicates the type of specimen, the time and date collected, and the signature of the collector. All specimens are sealed, and the date, time, and collector's initials are written on the seal. All containers are marked with a unique name and case number. A chain of custody is maintained in order to reasonably demonstrate to the court that the analysis results match the person from whom the specimens were taken.

Figure 11.1 Needle and spoon. These trappings of intravenous drug abuse were found on an individual. The spoon is a "cooker" that is used to melt heroin into liquid form. The needle still contains the blood of the deceased, who died of a heroin overdose. The syringe can be analyzed for heroin.

Figure 11.2 (a) Crack cocaine and cigarette papers. These objects were found in the clothing of a homicide victim. Crack cocaine in the "rock" form shown here can be smoked from a pipe. **(b) Marijuana**. Marijuana is often rolled in cigarette papers, such as those seen in **(a)**, to make marijuana cigarettes. If "spice" is suspected, the pathologist must alert the toxicologist to perform special testing.

Figure 11.3 Syringe tattoo. Tattoos, clothing, jewelry, belt buckles, paraphernalia, and other personal items alert the investigator to a drug-related death.

Figure 11.4 Suicide by suffocation. This individual took toxic levels of pain medication, placed the bag over his head, and then tied the rope. Published suicide literature was found nearby, instructing an individual on how to commit suicide in this fashion. The deceased had not been seen for a few days and was beginning to decompose.

Figure 11.5 (a–c) Nitrous oxide use causing suffocation. This individual used the depicted nitrous oxide canisters from a whipped cream dispenser to release the gas into a plastic bag. This bag was placed over his head, as shown. Note the belt, which was used to cinch the bag closed. The nitrous oxide replaces the oxygen in the bag, causing asphyxia. Nitrous oxide is a recreational drug that causes euphoria, a floating feeling, and laughter.

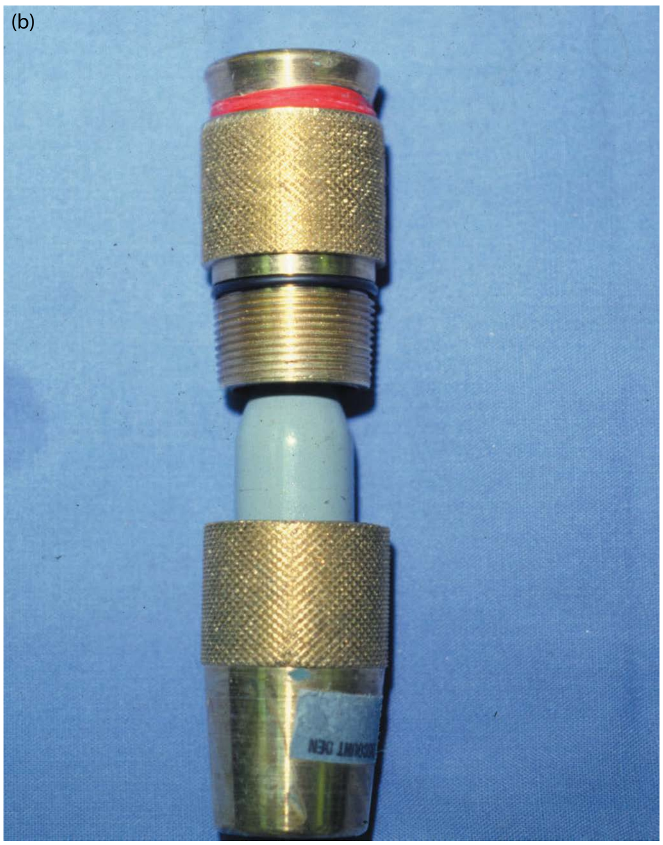


Figure 11.6 (a) Glue residue on the hand. This individual was found dead at his residence. He was seen sniffing or "huffing" glue previously. **(b) Glue container**. A search of the house revealed this glue container. The decedent's blood can be tested for the volatile compounds in glue.

CHAPTER 12

INVESTIGATING NATURAL DISEASES

Over half of all deaths investigated by a medical examiner or coroner's office involve natural diseases, with the most common of these diseases being cardiovascular disease. Natural disease processes alter the way the body reacts to and repairs injuries. The older the person is, the more likely natural disease has a role in the death. This concept can work in reverse. One can erroneously assume that since the person is young, natural disease is not a factor in the death. People with medical problems are frequently taking prescription medications, and these medications can have a bearing on the cause and manner of death. Many people have unknown or undiagnosed natural diseases which become manifest in sudden, unexpected death. A common history in these cases is that "he hadn't seen a doctor in years," or "he didn't believe in doctors." In the author's experience, the result is that the first doctor he sees is the pathologist, who diagnoses what was a treatable natural disease such as cardiovascular disease. For these reasons, it is useful for anyone investigating deaths to be familiar with common medical diseases and conditions, as well as the terminology.

SUDDEN DEATH

Sudden death is a term that is used frequently in death investigation, but the meaning of the phrase can be ambiguous. In some situations, death can literally be *instantaneous*, such as with a massive pulmonary embolus. In others, such as a myocardial infarction, the death can be instantaneous, or take minutes to hours or longer. *Sudden cardiac death* is a sudden, unexpected death from cardiac causes within 1 hour of the onset of symptoms (Kumar, 2015). In some cases, the person is found and resuscitated, supported by ventilators and medical care, only to be declared braindead days later. Some authors consider "true" sudden death as instantaneous death, occurring within seconds of the onset of symptoms (Wagner, 2009). Some use the modifier "near" when describing this situation, such as "near" sudden infant death syndrome. In all of these examples, the death is sudden and unexpected, but the actual time of death varies widely.

In some death investigations, the issue of survival time can become important. This is true in cases where actions were carried out by some person at the crime scene, and if the deceased was instantaneously dead, then another person could have carried out these actions. Depending on the disease or injury and the actions taken, the pathologist can give an estimate as to whether those actions were possible. For example, a television was carried approximately 50 feet and dropped. If the person is found to have a massive pulmonary embolus or gunshot wound of the brainstem, moving a television 50 feet is unlikely. However, one must be careful in these estimates, because the author has seen a situation in which a person was stabbed in the heart and did carry a television 50 feet!

CARDIAC DISEASE

Ischemic Heart Disease (Ateriosclerotic Cardiovascular Disease)

Ischemic heart disease (IHD) generally refers to a group of afflictions related to the decrease or blockage of blood flow in the coronary arteries, the arteries that supply blood to the heart. "Ischemic" refers to the lack of oxygen and other nutrients that the blockage prevents the heart muscle from receiving. In the majority of cases, ischemia is due to atherosclerosis of the coronary arteries. Atherosclerosis is a type of arteriosclerosis in which yellowish "plaque" builds up over time, eventually narrowing the lumen (center) of the artery and shutting off the blood supply. In addition, this plaque and a weak blood vessel wall can balloon out (aneurysm) or rupture, further shutting off the blood flow. In less than 15% of cases, a blood clot (thrombus) can occlude the lumen as well.

IHD is responsible for 500,000 deaths each year (Kumar, 2015) and is the leading cause of natural death in men aged 20–65 years (Di Maio and Dana, 2006). Risk factors include family history of heart disease, advancing age, high cholesterol, diabetes, smoking, and high blood pressure. IHD results in four different serious or potentially fatal conditions:

- Myocardial infarction ("heart attack")
- Chronic IHD with heart failure ("congestive heart failure")
- Sudden cardiac death
- Angina pectoris (chest pain)

Myocardial infarction is the result of decreased blood flow to the heart muscle, causing death of the muscle. This decreased blood flow can be due to a sudden blockage of the coronary artery as the result of a blood clot or dislodged plaque, for example. In addition, when significant atherosclerotic blockage is present, the victim can put demand on the circulation by shoveling snow, for example, also

causing an infarction. If the decrease in circulation is large enough or is in critical areas of the heart, death can occur within seconds to minutes (sudden cardiac death). These victims often have a fatal cardiac arrhythmia (heart block, ventricular fibrillation, tachycardia, bradycardia, etc.). At autopsy, the heart muscle will look grossly and microscopically normal, as no infarction will be seen. In fact, if the victim lives for 4 hours after the infarction, only the earliest changes—"wavy fibers"—will be seen under the microscope. Only if the victim lives for over approximately 8–12 hours can the infarction be seen as mottling of the damaged muscle (Figure 12.1). After approximately 4–5 days, the dead muscle is very weak and at risk of rupture, causing a hemopericardium (Figure 12.2). The injury can heal, and after approximately 2 months leaves a characteristic whitish scar in the same area.

Chronic IHD occurs over a long period of time. These victims suffer gradual ischemic damage due to slowly clogging arteries. There may be a history of healed infarction, previous cardiac bypass history, or no history at all. In addition to angina, these patients may have a history or shortness of breath and ankle edema, the latter of which often requiring a diuretic (water pill), such as Lasix®. These patients can die suddenly due to arrhythmias, acute heart failure, pulmonary edema and myocardial infarction, among other conditions.

Sudden cardiac death affects 300,000–400,000 persons per year and is generally defined as a sudden unexpected death, related to cardiac causes, occurring 1 hour or less from the onset of symptoms (Kumar, 2015). Common causes related to sudden cardiac death are listed below:

- Idiopathic (no cause is found)
- IHD
- Myocarditis (inflammation of the heart)
- Congenital heart diseases
- Hypertensive heart disease (thick left ventricle and high blood pressure)
- Mitral valve prolapse
- Aortic or subaortic stenosis
- Hereditary syndromes, such as the long QT syndrome

In myocarditis, the pathologist examines the heart muscle under the microscope to look for inflammation and death (necrosis) of cardiac muscle cells. In sudden cardiac deaths, the conduction system can be examined microscopically by the pathologist in order to demonstrate inflammation or scarring. Since the conduction system is the "electrical system" of the heart, interruption can cause arrhythmias. The autopsy itself cannot prove arrhythmia, but finding an interruption of the conduction system can be strong evidence for a fatal arrhythmia. In some cases, the heart is grossly and microscopically normal, but the circumstances of the death appear to be cardiac in origin (angina or chest pain, shortness of breath, sudden collapse, etc.). The autopsy may only show pulmonary edema and congestion. These victims likely suffer a fatal arrhythmia, and the heart defect that caused the arrhythmia is simply not detectable by the autopsy.

RESPIRATORY SYSTEM

Upper Respiratory System: Epiglottitis and "Café Coronary"

The trachea connects the mouth and nose to the lungs, normally allowing the free exchange of air. Air must travel through the pharynx and larynx (voice box) as it travels down to the lungs. The epiglottis is a thumb-shaped flap that closes when one swallows so that food cannot go into the trachea and lungs. In acute epiglottitis, bacterial inflammation of the epiglottis can cause severe swelling, cutting off the airflow and causing death (Figure 12.3a and 12.3b). A severe allergic reaction can cause swelling of the epiglottis and other tissues in the throat, also resulting in death. Food and foreign objects (usually in children) can be caught here as well. In adults who are either under the influence of central nervous system depressants like alcohol or are debilitated, the risk of choking is increased. A "café coronary" is when a person chokes on food while eating in a restaurant. A choking person cannot talk, and may panic by getting up and running to the restroom, thus giving the appearance of a "coronary."

Lower Respiratory System

Pneumothorax

Pneumothorax simply means air in the chest (thoracic) cavity. If air leaks out of the lung, either spontaneously or by trauma, air goes into the thoracic cavity and the lung collapses. In patients with poor pulmonary function, or when severe or bilateral, if untreated, this may result in death. A chest tube removes the air and allows the lung to reinflate.

Pulmonary Thromboembolus

A thrombus is a blood clot. An embolus is anything moving through the vascular system, such as an air bubble, bullet, or blood clot. Most pulmonary thromboemboli are formed in the deep veins of the calf muscles. Once the clot forms, it can move up through the larger veins into the right side of the heart, where it then moves into the pulmonary arteries (Figure 12.4). If the clot is large enough, it can cause acute right heart failure and nearly instant death. Smaller clots might only block a smaller artery and cause a pulmonary infarct, sending a warning that a larger clot may follow. These patients have shortness of breath and chest pain. There can be a history of leg swelling, redness, and pain. Conditions that pose a risk for pulmonary thromboembolus include:

- Postoperative state, especially orthopedic and fracture cases
- Cancer
- Trauma
- Elderly, bedridden, and debilitated
- Family history
- Previous history

- Burns
- Myocardial infarction and atrial fibrillation
- Genetic disorders (e.g., Factor V gene)

Asthma

Asthma is a chronic inflammatory condition of the lungs in which the airways constrict (bronchospasm) and reduce airflow in the lungs. Symptoms include wheezing, shortness of breath, and coughing. Sudden death is a risk in a small percentage (less than 5%) of cases (Di Maio and Dana, 2006). Status asthmaticus is a sudden, severe asthma attack that can be fatal. If untreated, the lungs in status asthmaticus can appear overinflated at autopsy (Figure 12.5). Asthma patients usually have a long history of treatment, and the family is usually aware of the seriousness of the disease. Asthma "attacks" can be started by many different triggers, including allergies, drugs, stress, exercise, industrial toxins (e.g., red cedar dust in lumbering), and unknown causes.

Pneumonia

Pneumonia is a general term for inflammation of the lung. The source of the inflammation can be bacterial, viral, fungal, and chemical. The inflammatory process reduces the air exchange capacity of the lungs (Figure 12.6). Most patients who acquire pneumonia in the community seek treatment, making the number of fatal cases low. However, untreated, fatal cases of pneumonia are often found in alcoholics, drug addicts, debilitated and chronically ill patients, and those individuals with a weak immune system (immunosuppressed). Pneumonia is often a complication in many situations seen by the medical examiner/coroner. These include nearly any patient on a respiratory ventilator for a prolonged period of time, massive trauma patients, and burn patients. Patients who aspirate develop a chemical pneumonia from the gastric acid irritating the lung tissue, and then bacteria invade secondarily, causing further inflammation. Industrial exposure to certain compounds, like chlorine gas, can also cause chemical pneumonia.

Massive, Fatal Hemoptysis

Hemoptysis is coughing or "spitting up blood." Individuals with cancer of the lung or respiratory tree, tuberculosis, lung abscess, and aortic aneurysm eroding into the lung can experience a sudden, fatal hemoptysis. A common death scene finding is abundant blood in the bathroom. Ruptured esophageal varices, a complication of cirrhosis of the liver, should be ruled out.

Emphysema and Chronic Bronchitis: Chronic Obstructive Pulmonary Disease

The majority of these diseases are caused by cigarette smoking; approximately 10% of patients are nonsmokers (Kumar 2015). Emphysema and chronic bronchitis are both classified as chronic obstructive pulmonary disease. The lung tissue is damaged to the point at which the air exchange ability of the lung is gradually reduced and the air sacs dilate, trapping air. In later stages, these patients require continuous oxygen. If the oxygen is removed or the tank is empty, death can ensue. These patients are very vulnerable to dying from pneumonia. The inflammation hinders the air exchange ability of the small amount of lung tissue remaining.

Pulmonary Edema and Congestion

Congestion in the lungs is the accumulation of blood in the vascular system. This is commonly due to the blood being "backed up" in the lungs, not being moved out by the heart. Soon, pulmonary edema can occur as fluid or even blood leaks out into the air spaces (alveoli) (Figure 12.7a and 12.7b). The patient becomes short of breath and can ominously cough up a white, pink, or red foamy fluid. The air exchange ability of the lung is further compromised, which eventually makes the edema worse. Pulmonary edema is the end result of many different problems in the body. These problems include:

- Myocardial infarction and heart failure
- Drug overdose
- Shock
- Trauma
- Brain injury
- Brain hemorrhage and strokes
- Pneumonia and sepsis
- Any death in which the heart slowly fails

Acute respiratory distress syndrome or "shock lung" is a condition in which the lung capillaries are damaged, severely interfering with air exchange. This condition can be seen after shock, trauma, and sepsis.

GASTROINTESTINAL TRACT AND PANCREAS

Massive, Fatal Hematemesis (Vomiting Blood)

Hematemesis can come from the stomach or esophagus. Blood from the stomach can be dark and "coffee ground" appearing. Cirrhosis patients develop varices in the esophagus, which are dilated veins (Figure 12.8). Since cirrhosis renders the liver hard, blood backs up in the veins that connect to the liver. These veins can rupture spontaneously, causing death in 40%–50% of cases (Kumar 2015). Mallory–Weiss tears can cause severe bleeding. Severe vomiting and retching can cause a tear where the esophagus inserts into the stomach. Ulcers and cancers of the stomach can erode into a large blood vessel and cause severe bleeding as well. Stomach ulcers can also perforate the stomach wall, causing gastric juices to flow into the abdominal cavity, leading to a severe infection (peritonitis) and, at times, death (Figure 12.9).

Bowel Infarctions

If a portion of the small or large bowel dies, bacteria can invade the abdominal cavity and cause peritonitis with later sepsis and shock (Figure 12.10a and 12.10b). Bowel infarction

can be caused by atherosclerosis of bowel arteries, thrombosis, hernias (incarcerated), twisted bowel (volvulus), tumors, and adhesions (scars from old inflammation or surgery).

Pancreatitis

The pancreas contains many enzymes that aid in digesting food normally. If the pancreas becomes inflamed, these enzymes can be released into the abdominal cavity and the surrounding tissues can be digested (Figure 12.11). Pancreatitis is a serious condition that can lead to pancreatic hemorrhage, low serum calcium, sepsis, shock, and death. Pancreatitis can be seen in alcoholism and with stones blocking the drainage of the pancreatic ducts.

LIVER

Fatty Change or Fatty Metamorphosis

A number of conditions and toxins can cause fat to accumulate in the liver cells, giving the liver a yellowish gross appearance (Figure 12.12). While some cases of severe fatty liver are associated with sudden death, most cases are not fatal. Fatty liver is associated with many conditions and diseases, including:

- Alcohol abuse
- Diabetes
- Hepatitis
- Starvation
- Obesity
- Many drugs and toxins (e.g., tetracycline)

Cirrhosis

Cirrhosis is a response of the liver to damage over a period of time (Figure 12.13). Alcoholism is the cause most people think of as causing cirrhosis. Only approximately 10%–15% of alcoholics develop cirrhosis (Kumar, 2015). Hepatitis B and C (not hepatitis A), hemochromatosis (iron overload), and other conditions can also lead to cirrhosis. Some of these patients are eligible and can receive liver transplants.

In alcoholism, the development of cirrhosis seems to be mainly dependent on the amount of alcohol consumed and the inherited decrease of some enzymes that protect the liver. Since some major clotting factors are made in the liver, in the later stages of cirrhosis, these patients are prone to bleeding. The liver can fail outright, causing fatal metabolic problems in the body, such as elevated ammonia levels. Formation of varices in the esophagus, which are prone to bleed, is another complication. Cirrhosis is associated with sudden death, as is alcoholism.

Hepatitis

Hepatitis simply means inflammation of the liver. Normally, hepatitis refers to viral hepatitis, which includes hepatitis A, B, C, D, E, and G. Hepatitis A is acquired by ingesting virus-contaminated food or water. Though highly contagious, it is transmitted by contaminated feces, not blood. Hepatitis A does not cause chronic hepatitis or cirrhosis.

Hepatitis B, C, D, and G are all contracted by a blood-borne route and, less commonly, sexual intercourse. Hepatitis B, C, and D can cause chronic hepatitis, with hepatitis C being the most likely to do this. Cirrhosis and hepatocellular carcinoma are later complications.

The pathologist and everyone involved in handling the body and body fluids should treat every case as infectious, using universal precautions. While it is prudent to warn everyone involved in handling the body and bodily fluids that the deceased is known to have hepatitis, one should keep in mind that it is the unknown case that is the most dangerous.

VASCULAR SYSTEM

Aortic Aneurysm and Aortic Dissection

An aneurysm of the aorta is a ballooning of the wall. The wall can become weak due to atherosclerosis or elastic defects in the wall. At some point, the aneurysm can rupture, causing massive hemorrhage (Figure 12.14). Depending on the location, the blood can dissect into the pericardium, chest cavity, and the abdominal cavity.

An aortic dissection is a simple dissection of blood through a weakness in the aortic wall. As with an aneurysm, massive fatal hemorrhage can occur.

CENTRAL NERVOUS SYSTEM DISORDERS

Epilepsy (Seizure Disorder)

The history of seizure disorder warrants some investigation. Patients with generalized seizures (jerking movements of the entire body with loss of consciousness) are usually on medications, such as Dilantin® or Tegretol®, to decrease the frequency of seizures. If the patient stops taking the medication for some reason, the seizures can become more frequent. Prolonged seizures (status epilepticus) can be fatal, as effective breathing does not occur. Epileptics are at risk of sudden death, but the mechanism of death can be a seizure or a cardiac arrhythmia in some cases. If alcoholics suddenly stop drinking, seizure-like activity ("alcohol withdraw seizures") can result, which can also be fatal. For this reason, some alcoholics are given seizure medications.

At autopsy, the findings usually only include pulmonary edema and contusion of the tongue. Occasionally, the seizure victim will display "instant rigor mortis," with body parts recapitulating the spasm of the seizure (Figure 12.15). The brain usually does not show an abnormality, but when it does, a tumor, vascular malformation, or an old injury is seen (post-traumatic seizure disorder).

Subarachnoid Hemorrhage

Subarachnoid hemorrhage in the absence of trauma is usually due to a ruptured berry (saccular) aneurysm or arteriovenous malformation (AVM). The subarachnoid layer of the brain is the tight layer around the outside of the brain, so when the brain is removed, the blood is kept close to the brain by this tightly fitting layer. The aneurysm is on the bottom of the brain, in a collection of arteries called the "circle of Willis" (Figure 12.16a–d). In total, 80% of people die within 24 hours of rupture. Some patients experience the rupture while performing some rigorous physical activity, such as sexual intercourse or lifting objects.

Strokes

Strokes can either be hemorrhagic or ischemic. In both cases, there is significant damage to brain tissue. This damage can cause death by brain swelling, hemorrhage, and direct damage to vital centers of the brain. Causes of a hemorrhagic stroke include hypertension, AVM, anticoagulant overdose, and tumors (Figure 12.17a and 12.17b). Causes of an ischemic stroke include atherosclerosis and other blockage of arteries, venous thrombosis and global ischemia from lack of blood flow in all areas, such as in a cardiac arrest patient.

Meningitis

Meningitis is the inflammation of the meninges, the layers that cover the brain and spinal cord. The most common cause is bacterial, though viruses and fungi can cause meningitis as well. The meninges appear cloudy, and occasionally pus can be seen. The cerebrospinal fluid should be cultured if meningitis is suspected, so that those in contact with the deceased can be given prophylactic treatment. Common bacteria causing meningitis include *Neisseria meningitidis* (meningococcus) and *Streptococcus pneumoniae*. Meningococcus can present in young adults who live close together, such as military recruits and college students. A vaccine is available, however. These patients present with headache, neck pain, and fever.

Encephalitis

Encephalitis is inflammation of the brain, usually caused by viruses. Recently, an epidemic of West Nile viral encephalitis broke out in the Midwest. Other types of encephalitis in the United States include Eastern and Western equine, Venezuelan, St. Louis, and La Crosse. These patients present with headache, sleepiness, seizures, confusion, and coma. These cases are important to identify for public health reasons.

SYSTEMIC DISEASES

Carcinomatosis

The term "cancer" refers to an abnormal growth of cells in the body that have the capacity to grow and spread throughout the body (metastasize). "Malignant" refers to the behavior of the cancer causing significant illness and/or death. Cancer is not simply one disease. Virtually every organ and tissue in the body has a malignant counterpart that can cause severe health problems, including death, by local or distant spread. Each type of malignancy behaves differently in the body. The same cancer in two different people can even behave differently. In most malignancies, the patient receives an extensive diagnostic workup, including surgery with resection or biopsy of the tumor, x-rays, and scans. After the malignancy is classified and the extent of the spread of the tumor is determined, treatment can begin.

Cancer patients can appear to be doing well and free of disease (remission), and then suddenly fall ill again (relapse). This phenomenon can be difficult for families, especially when the person dies suddenly after a relapse. The families may blame the care or other factors for the death and demand an autopsy. The medical records and the medical care should be investigated. Often, an autopsy is conducted in order to answer these questions raised by the family.

Cancer patients can die suddenly for several reasons. These include:

- Erosion or impingement of the tumor on adjacent structures—a lung cancer can erode into an artery, causing hemorrhage.
- Production of byproducts that harm the body—tumors can cause the body to produce calcium or form blood clots.
- Secondary infections—cancer patients are very susceptible to sepsis, pneumonia, and other infections.
- Cancer cachexia—it is well known that cancer patients "waste away" and have poor appetites. The patient loses weight and experiences muscle wastage to the point where death can occur.
- Carcinomatosis—cancer patients, particularly those with widely spread malignancies, can die suddenly with no additional apparent mechanism of death (Figure 12.18a–d).

Sepsis, Shock, and Death

Sepsis is a generalized bacterial infection in the blood. Sepsis is a serious, life-threatening infection that must be treated immediately. The bacteria can quickly cause vascular collapse in the body (shock) and disseminated intravascular coagulation (DIC). Certain bacteria, most notoriously Gram-negative bacteria, can more rapidly cause these problems. DIC is a process by which the bacteria cause most of the clotting factors to be activated throughout the body, consuming them. At this point, with most of the factors consumed, the patient begins to bleed uncontrollably. There is no good treatment for DIC, except supporting the patient, administering blood products, and treating the infection that caused it.

Diabetes Mellitus

The hallmark of diabetes mellitus is elevated blood glucose due to the lack of insulin production by the pancreas. There

are two types of diabetes, namely types I and II. Type I is a more severe form that usually starts in childhood and becomes more severe with age. Type I can develop at any age. The patients are more "brittle," showing greater variation glucose levels and requiring more insulin.

Type II diabetes is sometimes referred to as "adult-onset diabetes." Obesity, poor diet, and lack of physical activity are strong factors in the development of this disease later in life. These patients can often reduce their insulin requirements by losing weight and modifying their diets. Both types of diabetes show genetic factors.

There are many long- and short-term serious complications of diabetes. If the patient does not take insulin, the blood glucose can increase to 600 mg/dL or greater over a short period of time, potentially causing a "diabetic coma," which is life threatening. In addition, if too much insulin is given, the blood glucose can drop to below 40 mg/dL, causing unconsciousness and death unless glucose can be given immediately. The long-term potentially lethal complications of diabetes include:

- High blood pressure
- Stroke
- Coronary atherosclerosis and myocardial infarction
- Systemic atherosclerosis, involving the aorta and leg arteries
- Kidney disease leading to renal failure

Alcohol Abuse

Alcohol (ethanol) abuse is responsible for at least 100,000 deaths per year in the United States, and ethanol is the most commonly abused drug worldwide (Kumar 2015). Anyone who has worked in law enforcement, medicine, or death investigation is well aware of the effects of alcohol on human behavior.

Initially, alcohol produces euphoria or exhilaration, followed by loss of inhibition, talkativeness, slurred speech, unsteady gait and other balance and coordination problems, drowsiness, stupor, and finally coma. Ultimately, ethanol is a depressant, leading to a wide variety of behaviors, including suicide and homicide.

A blood level of alcohol of 0.08 g/dL is the legal limit for driving in most states, though impairment begins at as low as 0.03 g/dL. To reach 0.08 g/dL in a 175-lb person requires approximately four 12-ounce beers, four 1.5-ounce 90-proof spirit drinks, or four 6-ounce glasses of wine. Drowsiness and stupor can occur at 0.2 g/dL or less in nondrinkers, and death can occur at 0.25 g/dL or greater. Alcoholics can tolerate very high levels, and can even drive, walk, and perform other tasks at 0.50 g/dL or greater. Postmortem levels of ethanol might not reflect the highest level attained after drinking, since the person might have lived in a coma for a period of time, metabolizing the ethanol.

Toxicology laboratories measure blood ethanol, but hospital laboratories measure serum alcohol. This can create some confusion, since the two results are not interchangeable. Generally, serum levels are 1.18-times the blood levels, or 18% higher. Therefore, a *serum* alcohol level of 0.118 g/dL (118 mg/dL or 118 mg %) corresponds to a *blood* level of 0.100 g/dL.

Alcohol abuse and alcoholism affect many organs and tissues. Some of the effects are reversible, while others are not. These effects include:

- Nervous system—unsteady gait and memory loss
- Liver—fatty change and cirrhosis
- Pancreas—acute and chronic pancreatitis
- Heart—atrial fibrillation and cardiomyopathy
- Stomach—gastritis
- Skeletal muscle—weakness and pain
- Testes—atrophy
- Reproductive—fetal alcohol syndrome (birth defect)
- Metabolic—magnesium and thiamine deficiencies

HUMAN IMMUNODEFICIENCY VIRUS/ACQUIRED IMMUNE DEFICIENCY SYNDROME

Human immunodeficiency virus (HIV) is a virus that attacks the white blood cells, causing immune deficiency and leaving the body susceptible to opportunistic infections and cancers. Acquired immune deficiency syndrome (AIDS) is the name of this syndrome. By the end of 2002, nearly 900,000 cases were reported in the United States, and AIDS was the second most common cause of death in individuals aged between 25 and 44 years (3). HIV is most commonly transmitted by sexual intercourse, both heterosexual and homosexual. Intravenous drug users sharing needles is another mode of infection. HIV can be acquired by needle sticks or other exposures to body fluids. Fortunately, cases of persons contacting HIV from a deceased person are very rare. Using universal precautions will prevent the transmission of HIV.

The primary problem with HIV infection is the loss of a white blood cell called the $CD4^+$ helper–inducer T cell. This allows normally harmless bacteria, protozoa, and other organisms to infect the body. In addition, the patient is susceptible to certain cancers, such as lymphoma. Most HIV patients are well known in the medical community, and their deaths do not come under the medical examiner's jurisdiction unless there is a homicide or other unnatural death.

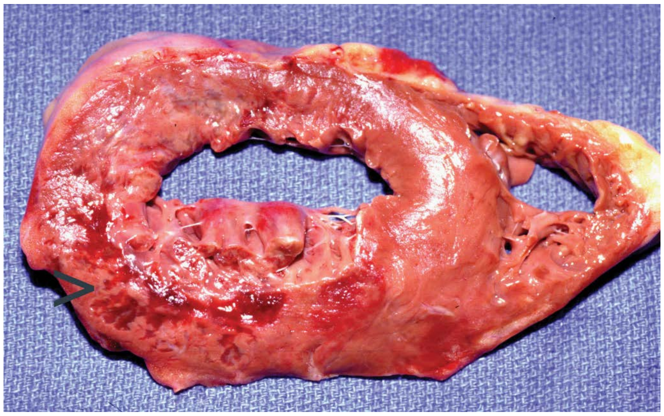


Figure 12.1 Acute myocardial infarction. This myocardial section shows mottling in the lateral left ventricular wall, suggesting early myocardial infarction. Infarction will be confirmed by examining tissue sections with the microscope. Marked mottling can be seen at the bottom of the image, which is the anterior left ventricular wall.

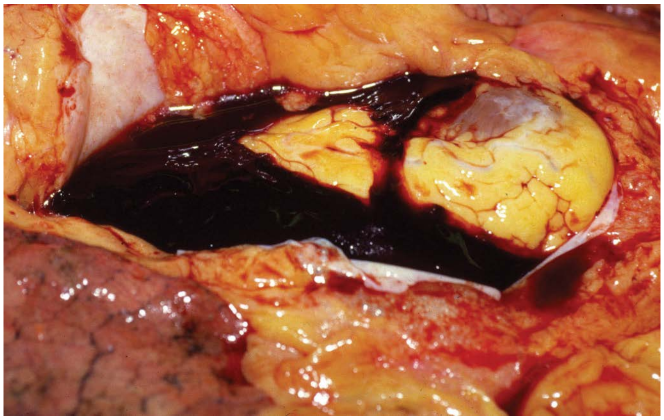
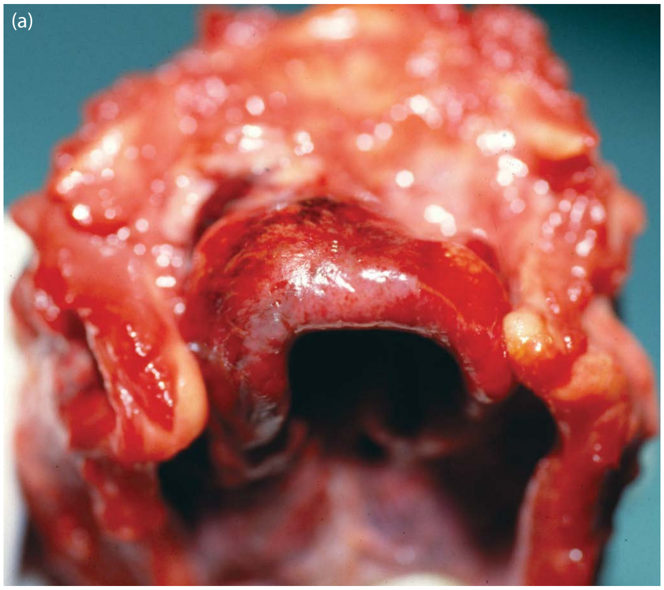


Figure 12.2 Hemopericardium. Blood clot can be seen filling the pericardium. This patient had suffered a myocardial infarction approximately 5 days previously. The infarcted (dead) heart tissue burst open, allowing for hemopericardium. The blood in the pericardium interferes with the contraction of the heart (cardiac tamponade) and can cause cardiac arrest.



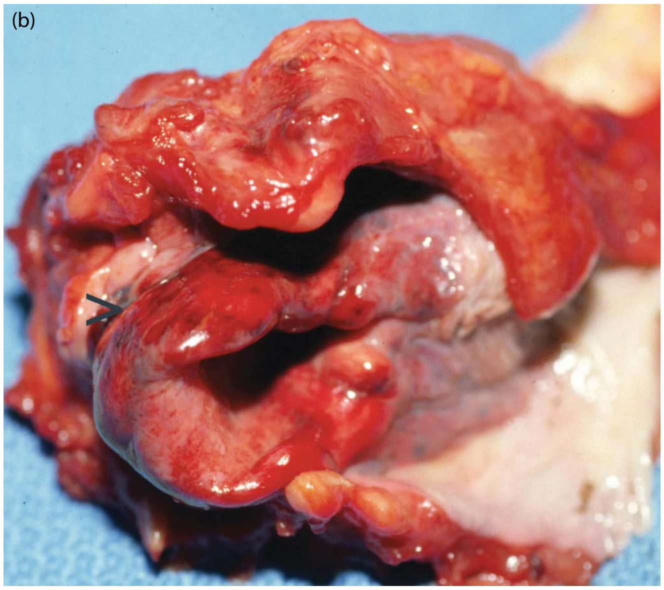


Figure 12.3 (a and b) Epiglottitis. Edema and swelling of the epiglottis can cause occlusion of the airway and death. The rounded, meaty-red, swollen epiglottis shown here was the result of group B *Streptococcus* infection. The victim died suddenly with "trouble breathing" after having a severe sore throat for several days.

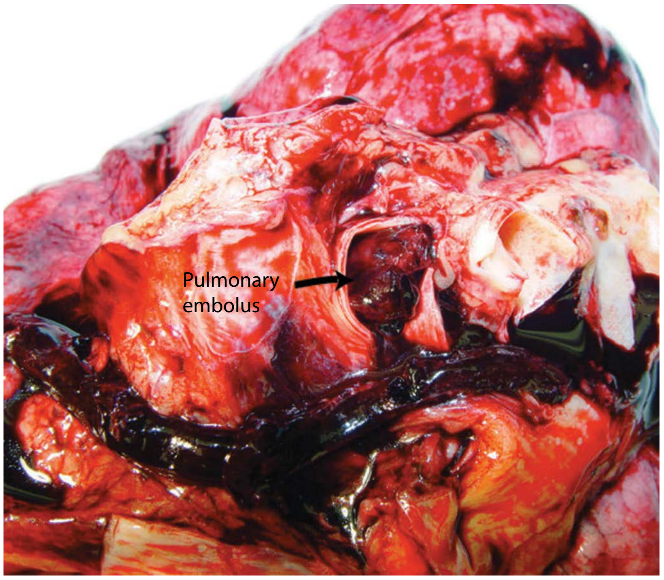


Figure 12.4 Pulmonary embolus. Blood clots, usually from the lower extremities, can travel up the venous system to the right side of the heart, occluding the pulmonary arterial system. A clot of this size can cause nearly instantaneous death.

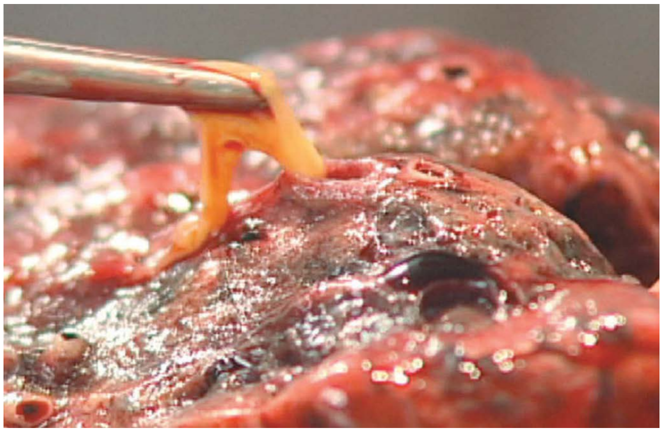


Figure 12.6 Purulent material in the smaller bronchus. On further sectioning, this lung shows yellowish, mucoid pus in the bronchi, indicating bronchopneumonia.

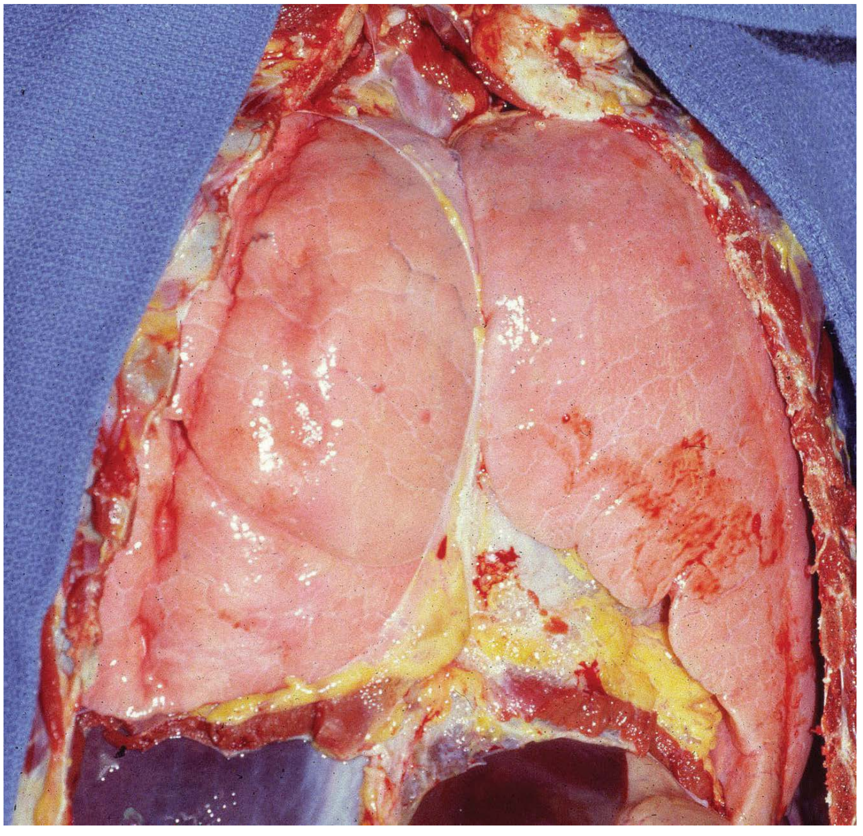


Figure 12.5 Hyperinflated asthmatic lungs. The lungs here show hyperinflation due to trapping of air. This patient died of a sudden asthma attack (status asthmaticus), in which bronchial spasm and plugging of mucous hamper breathing, causing air to be trapped.


(a)


(b)

Figure 12.7 (a and b) Pulmonary edema. Pink to red fluid exuding from the mouth and nose indicates severe pulmonary edema. This fluid can be propelled upward from the lungs after death, especially if the body falls in a position where gravity allows it to flow out. Centrally in the bronchus, the lung section shows edema fluid, characterized by fluid exuding from the air-filled spaces, producing bubbles (arrow). Common causes of pulmonary edema include heart failure, drug overdoses, and central nervous system pathology. Fluid engorges the vascular system, causing fluid to exude into the air spaces, mixing with air, forming a foamy, bloody fluid.

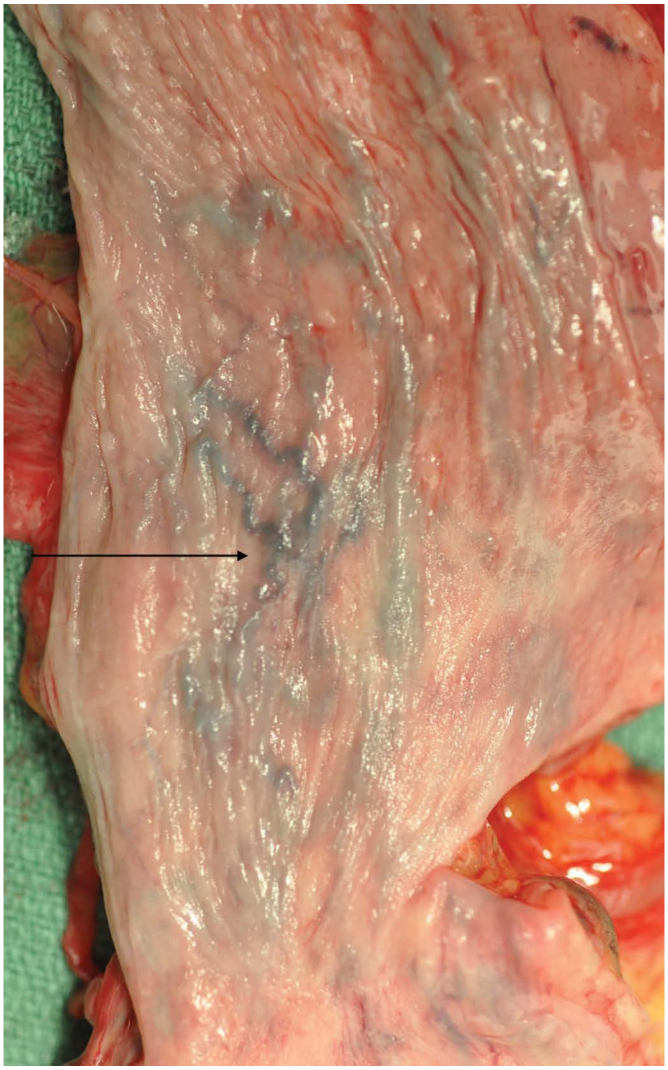


Figure 12.8 Esophageal varices. Patients with cirrhosis develop dilated, delicate veins in the esophagus, called varices. Since cirrhosis renders the liver hard, increasing the vascular pressure, blood backs up in the veins that connect to the liver. These veins can rupture spontaneously, causing death in 40%–50% of cases.

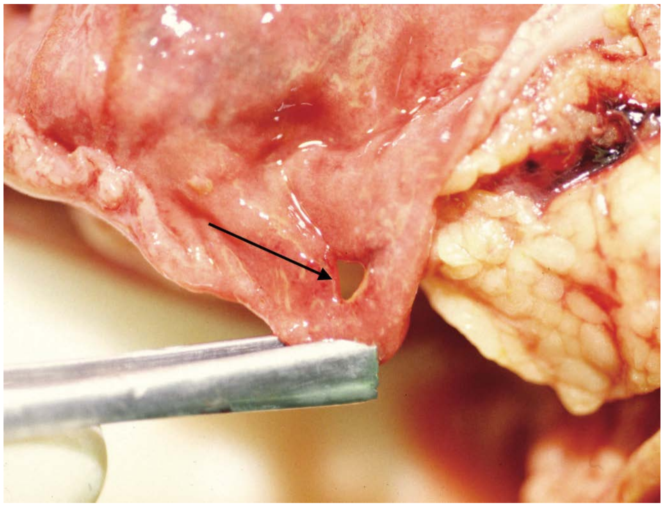


Figure 12.9 Perforated gastric ulcer. Central, above the forceps is a hole that goes completely through the stomach. Once the stomach perforates, the situation is life threatening, as the patient needs immediate surgery. Perforation causes a near-immediate chemical (due to stomach acids) and bacterial peritonitis, leading to infection and death unless immediate medical attention is sought.

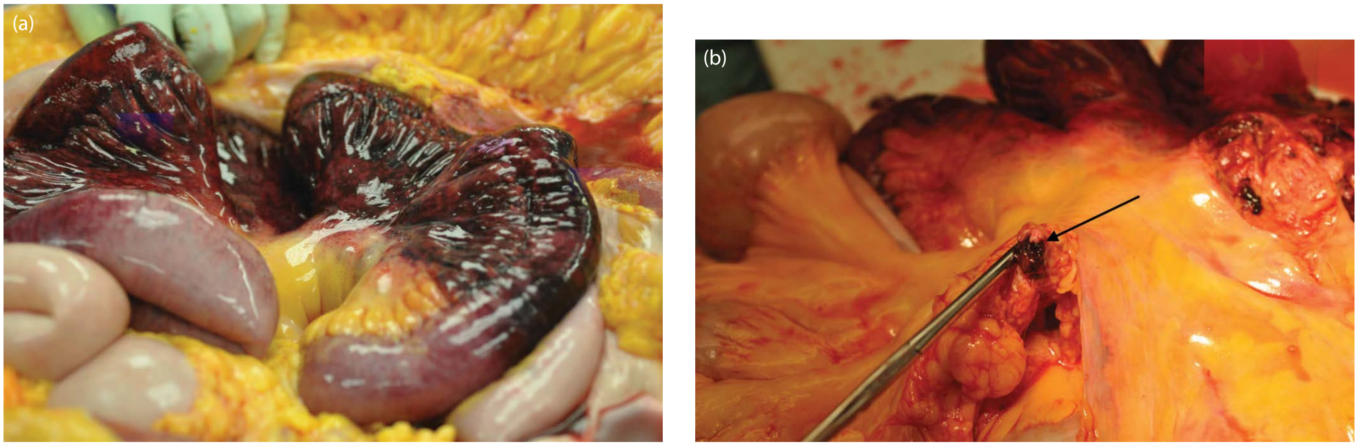


Figure 12.10 Small bowel infarction. (a) Bowel infarction will cause shock, peritonitis, and death if not treated immediately by surgery. Bacteria from the dead bowel seep into the peritoneum, where the bacteria can easily spread throughout the body, causing shock and death. **(b)** A large thrombus was found in a large mesenteric vessel, stopping blood flow and causing infarction.

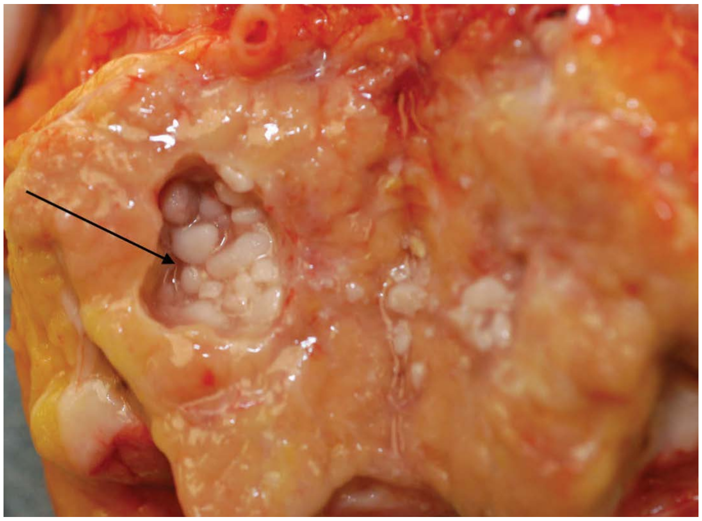


Figure 12.11 Pancreatitis. If the pancreas becomes inflamed, tissue-digesting pancreatic enzymes can be released into the abdominal cavity and the surrounding tissues can be digested. This image shows chronic pancreatitis with reactive calcification "stones." Pancreatitis is a serious condition that can lead to pancreatic hemorrhage, low serum calcium, sepsis, shock, and death. Pancreatitis can be seen in alcoholism and with stones blocking the drainage of the pancreatic ducts.

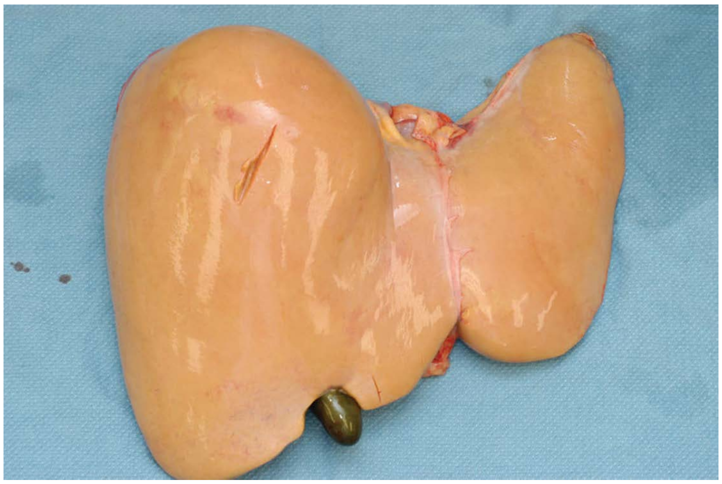


Figure 12.12 Fatty liver. Fatty liver can be seen in many conditions (see text). When the liver is acutely damaged by drugs, toxins, or diseases, the response is for the cells to become fatty. The degree of fatty change is determined under the microscope.

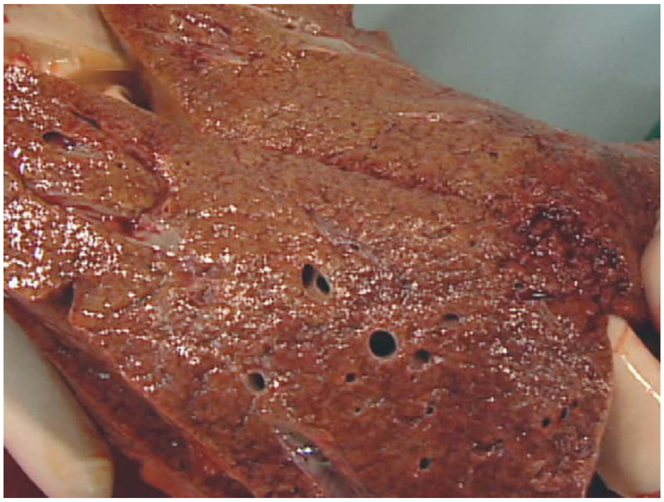


Figure 12.13 Cirrhosis of the liver. The sections of liver shown are very hard. Cirrhosis is, simply, a scarring of the liver. It is the way the liver reacts to an injury over a period of time. The injury can be due to alcohol, an acetaminophen overdose, or chronic ischemia due to heart failure. In cirrhosis, the liver becomes very hard, so that blood cannot flow normally through the liver. This causes the blood to back up elsewhere in the body, such as the esophagus (esophageal varices). In addition, the liver begins to fail due to a lack of cells to do the work, such as making clotting factors. As a result, the patient is prone to spontaneous bleeding. A common problem is for a cirrhotic patient to rupture the dilated veins around the esophagus, and clotting is less likely to occur. When advanced, this condition is irreversible, and very commonly fatal.

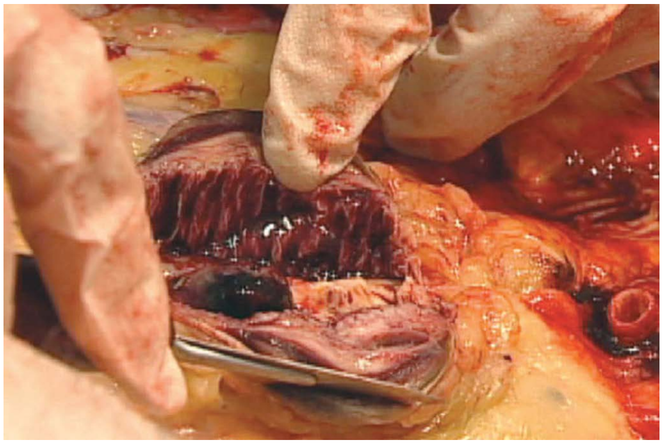


Figure 12.14 Abdominal aortic aneurysm. The aneurysm is cut open to reveal a thick, layered aneurysm wall. The finger is pointing at this wall. Focal hemorrhage into the wall can be seen below. Aneurysms that rupture during life cause massive internal bleeding and are often fatal unless prompt, emergent vascular surgery is performed.

Figure 12.15 Pedal spasms in a seizure death. Generalized seizures (grand mal) cause violent convulsions. If these convulsions are prolonged, the victim cannot breathe effectively, and death ensues. In this case, rigor occurred quickly due to the intense muscular activity of the seizure, showing the spasms of the foot.

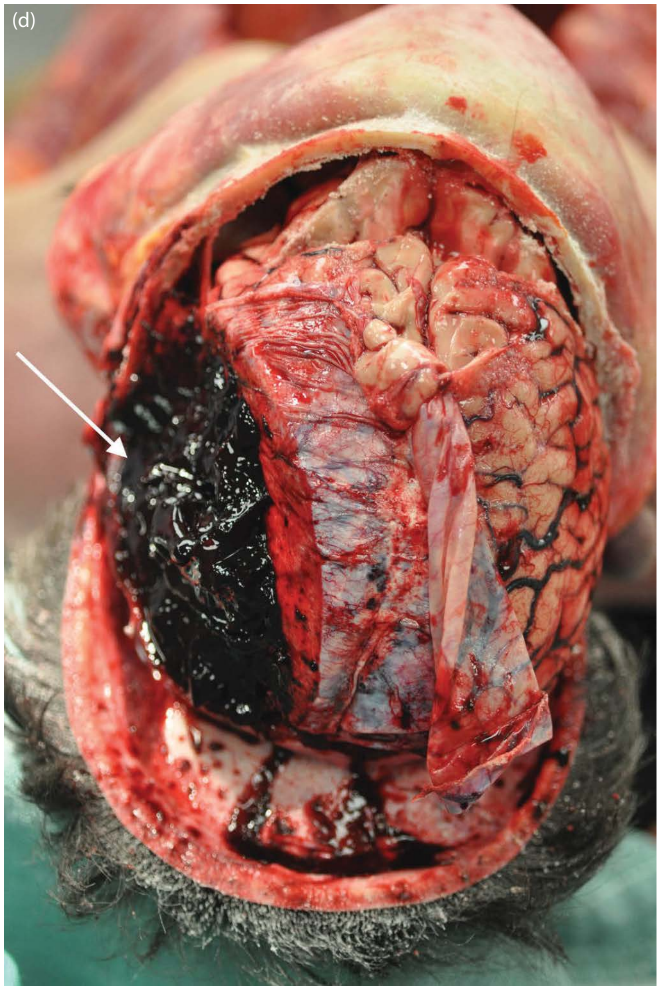


Figure 12.16 Subarachnoid hemorrhage and ruptured berry (saccular) aneurysm. (a and b) An aneurysmal blood vessel at the base of the brain can rupture spontaneously, causing subarachnoid hemorrhage. Blood spreads out beneath the subarachnoid layer, but concentrates at the base of the brain. **(c)** A berry or saccular aneurysm is commonly found near or in the circle of Wills at the base of the brain. The 'berry' is shown between the 2- and 3-cm marks, and the normal vessel is shown between the 3- and 4-cm marks. **(d)** Epidural hematoma is shown here so that it can be contrasted with subarachnoid hemorrhage. The reader should note that the hematoma is above the arachnoid layer and dura mater layer, causing a shift in the brain away from the clot. Epidural hematomas are usually seen with a skull fracture, and therefore are not natural disease processes.

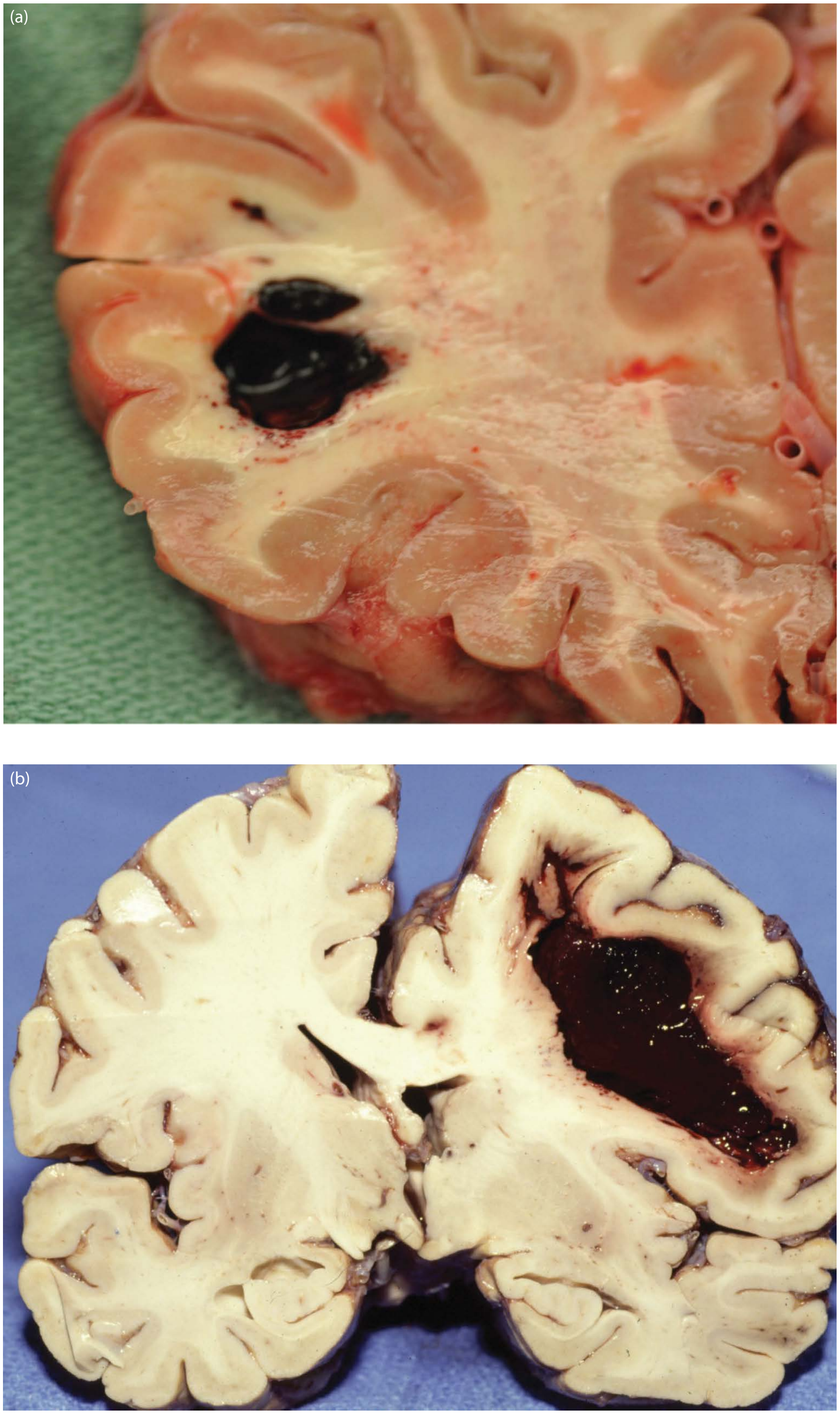


Figure 12.17 Intracerebral hemorrhage. (a and b) These sections of brain show hemorrhage in the white matter. These patients had histories of hypertension that, if untreated, greatly increases the risk of intracerebral hemorrhage (stroke).

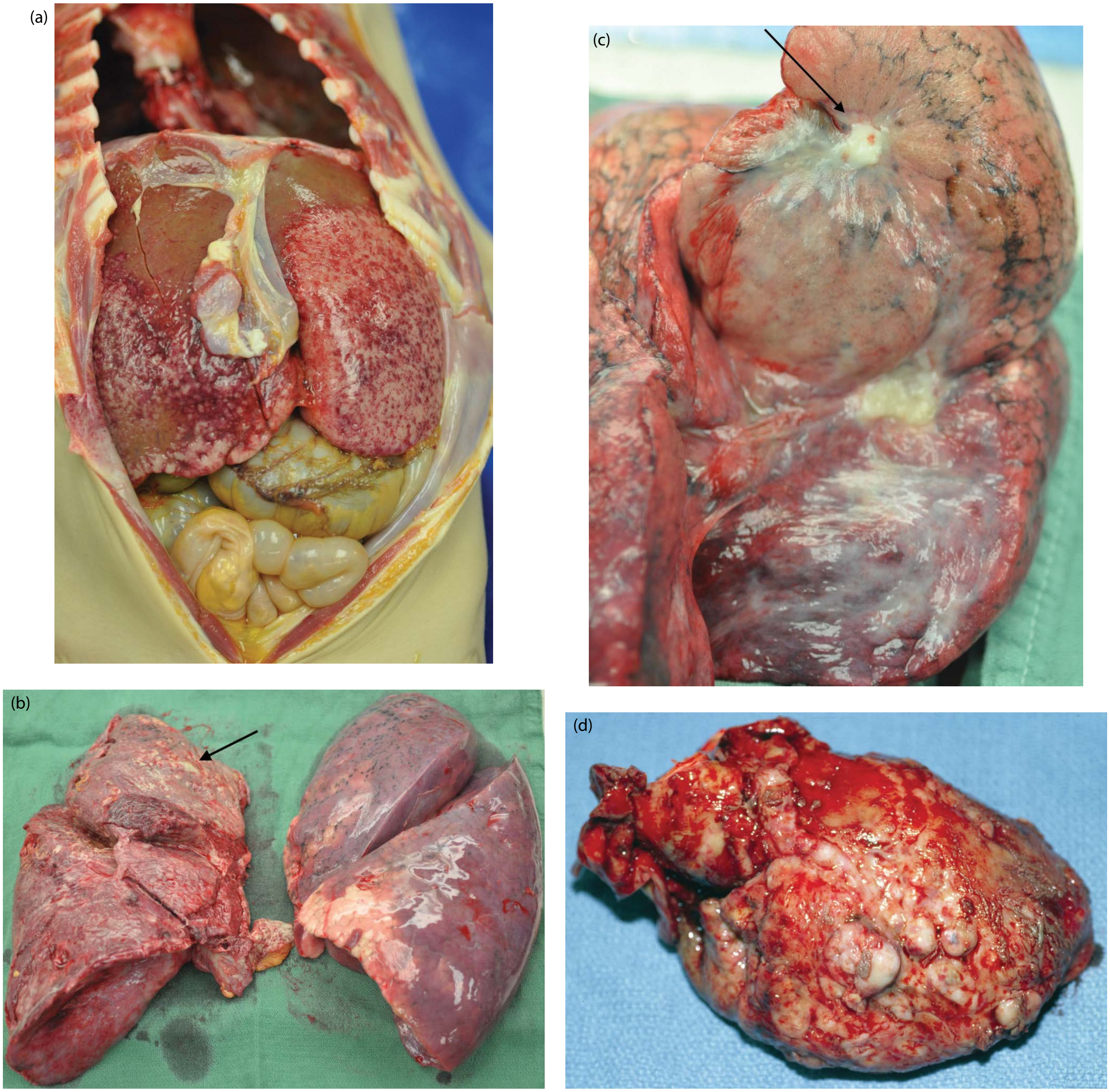


Figure 12.18 Carcinomatosis. Cancer can spread locally in the same organ or tissue and through the entire body. The tumor can directly interfere with organ function or cause other derangements in the body, such as blood clots. Paradoxically, patients can seem to be improving and then die suddenly. **(a)** This image shows a carcinoma that spread to the liver, nearly replacing it. **(b and c)** These images show a tumor that spread within the lung. **(d)** This image is of a carcinoma of the pericardium.

REVIEW QUESTIONS: PUTTING IT ALL TOGETHER

Answer questions 1 through 16 by choosing:
"A" if a, b, and c are true
"B" if a and c are true
"C" if b and d are true
"D" if d only is true
"E" if a, b, c, and d are true

1. The following types of deaths usually require an autopsy:
   a. Deaths of prisoners
   b. Deaths in the workplace
   c. Deaths within months of a traumatic accident
   d. Accidental deaths where there is no witness

2. The following are valid reasons for performing an autopsy in the case of an apparent homicide due to a single gunshot wound of the head:
   a. To confirm the cause of death
   b. To document the injuries
   c. To obtain adequate toxicology specimens
   d. To retrieve the bullet for further study

3. Reliable methods of identifying a badly burned body that would likely stand up to legal challenge include:
   a. DNA analysis
   b. Dental examination and records
   c. A uniquely numbered prosthesis
   d. Location; victim was the sole resident of the home

4. The following statements about the external examination are true:
   a. Universal precautions should be observed in all autopsies
   b. Nearly all trace evidence should be collected from the body at the scene
   c. The clothing should not be cut off in homicides
   d. All bodies must be x-rayed before an autopsy

5. These facts related to the four signs of death are true:
   a. Rigor mortis is accelerated by cold conditions
   b. Body temperature always drops at a rate of 1.5°F per hour
   c. Livor mortis is permanently fixed after 12 hours
   d. Decomposition rate is very dependent on environmental conditions

6. The following statements about documentation of injuries are true:
   a. Many states have laws restricting the use of autopsy images
   b. Both sketches and photographs are useful in documenting injuries
   c. Injuries should be carefully cleaned to show wound configuration
   d. Documentation of injuries is essential for other experts to review

7. Radiographs are useful supplements to the autopsy in the following ways:
   a. To find and enumerate bullets
   b. To identify remains by dental fillings
   c. To evaluate abusive fractures in children
   d. To diagnose pneumonia

8. Lacerations are defined by:
   a. Undermined margins
   b. Tissue bridging
   c. Abraded margins
   d. Jagged configurations

9. Blunt force injuries include:
   a. Lacerations
   b. Contusions
   c. Abrasions
   d. Cuts

10. Sharp force injuries include:
    a. Stab wounds
    b. Defense wounds
    c. Incised wounds
    d. Lacerations

11. The following statements about gunshot wounds are true:
    a. Intermediate-range gunshot wounds are defined by stippling
    b. Contact wounds show soot deposition in and around the wound
    c. Undetermined-range wounds show no soot or stippling
    d. Hard contact wounds can show some marginal tearing

12. The findings of the external examination direct the pathologist toward internal conditions, diseases, and injuries. Which of these external findings are matched with the appropriate internal findings?
    a. Laceration of scalp—skull fracture
    b. Crepitus of chest wall—pneumothorax
    c. Distended abdomen—lacerated liver

   d. Contusions of neck and abrasions of mouth—fracture of hyoid bone

13. The following statements are false:
   a. Pulmonary emboli are usually found in the pulmonary vein branches
   b. The heart weight is less than normal in hypertension
   c. The spleen's capsule is thin and easily torn on removal
   d. The neck dissection is performed after the viscera are removed

14. The following are important objectives of the individual organ examination:
   a. To perform gross and microscopic examinations in order to diagnose disease
   b. To describe and record pertinent findings
   c. To document diseases and injury by photography, as appropriate
   d. To preserve key tissues for later examination

15. These statements concerning the neck tissue examination are true:
   a. The epiglottitis can cause fatal swelling and occlusion of the airway
   b. An emergency airway is typically made in the thyroid cartilage
   c. Hyoid and superior thyroid cartilage fractures are associated with strangulation
   d. Cricothyroidotomies are made just below the hyoid bone

16. Which of the following match the correct disorder with the organ that most commonly displays the disorder?
   a. Anthracosis—lung
   b. Chronic passive congestion—liver
   c. Arteriosclerosis—kidney
   d. Serous cystadenoma—prostate

For questions 17 through 20, choose the best answer.

17. Which answer depicts the proper order of tissue layers of the head?
   a. Skin—skull—galea aponeurotica—dura mater—brain
   b. Skin—dura mater—skull—galea aponeurotica—brain
   c. Skin—galea aponeurotica—skull—brain—dura mater
   d. Skin—galea aponeurotica—skull—dura mater—brain

18. Why should the head and brain be subject to examination in all forensic autopsies?
   a. Most states require it by law
   b. For forensic research purposes
   c. Many injuries and conditions cannot be seen externally
   d. Computerized axial tomography scans miss many injuries

19. Which of the following is not a manner of death to be recorded on the death certificate?
   a. Homicide
   b. Suicide
   c. Natural
   d. Unnatural

20. The specimen of choice for determining possible hyperglycemia is:
   a. Blood
   b. Bile
   c. Vitreous fluid
   d. Urine

ANSWERS

1. E
2. E
3. A
4. A
5. D
6. E
7. A
8. A
9. A
10. A
11. E
12. E
13. B
14. E
15. B
16. A
17. D
18. C
19. D
20. C

GENERAL REFERENCES AND SUGGESTED READING

Adelson, L.A., *The Pathology of Homicide*, Charles C. Thomas Publisher, Springfield, 1974.

Brogdon, B.G., *Forensic Radiology*, CRC Press, Boca Raton, 1998.

Clark, S.C., Ernst, M.F., Haglund, W.D. et al., *Medicolegal Death Investigator*, Occupational Research and Assessment, Inc. 1996.

Collins, K.A. and Hutchins, G.M., *Autopsy Performance and Reporting*, 2nd ed., College of American Pathologists, Chicago, 2003.

Cotran, R.S., Kumar V. and Collins, T., *Robbins Pathological Basis of Disease*, 7th ed., W.B. Saunders Co., Philadelphia, 2003.

Di Maio, D.J. and Di Maio, V.J.M., *Forensic Pathology*, Elsevier, New York, 1989.

Di Maio, V.J.M., *Gunshot Wounds, Practical Aspects of Firearms, Ballistics and Forensic Techniques*, Elsevier, New York, 1990.

Di Maio, V.J.M. and Dana, S.E., *Handbook of Forensic Pathology*, 2nd ed., CRC Press/Taylor & Francis Group, Boca Raton, 2006.

Dix, J., *Color Atlas of Forensic Pathology*, CRC Press, Boca Raton, 2000.

Dix, J., *Handbook for the Death Scene Investigator*, CRC Press, Boca Raton, 1999.

Dix, J. and Graham, M., *Time of Death, Decomposition and Identification, an Atlas*, CRC Press, Boca Raton, 2000.

Ellenhorn, M.J., *Medical Toxicology, Diagnosis and Treatment of Human Poisoning*, 2nd ed., Elsevier, New York, 1997.

Froede, R.C., Ed., *Handbook of Forensic Pathology*, 2nd ed., College of American Pathologists, Chicago, 2003.

Geberth, V.J., *Practical Homicide Investigation*, 4th ed., CRC Press/Taylor & Francis Group, Boca Raton, 2006.

Haglund, W.D. and Sorg, M.H., Eds., *Forensic Taphonomy—The Post Mortem Fate of Human Remains*, CRC Press, Boca Raton, 1996.

Hanzlick, R., *Death Investigation Systems and Procedures*, CRC Press Taylor & Francis Group, Boca Raton, 1997.

Karch, S.B., *The Pathology of Drug Abuse*, CRC Press, Boca Raton, 1993.

Ludwig, J., *Handbook of Autopsy Practice*, 3rd ed., Humana Press, New Jersey, 2002.

Mortiz, A.R., Classical mistakes in forensic pathology, *American Journal of Clinical Pathology*, 26, 1383–1397, 1956.

Rohen, J.W. and Yokochi, C., *Color Atlas of Anatomy*, 3rd ed., Igaku-Shoin, New York, 1993.

Spitz, W.U., Ed., *Medicolegal Investigation of Death*, 4th ed., Charles C. Thomas Publisher, Springfield, 2004.

Stimson, P.G. and Mertz, C.A., Eds., *Forensic Dentistry*, CRC Press, Boca Raton, 1997.

Wagner, S.A., *Color Atlas of the Autopsy*, CRC Press/Taylor & Francis Group, Boca Raton, 2004.

Wagner, S.A., *The Autopsy, Chapter One: Unraveling Life's Mysteries*, video tape, 30 min., Wagner Research, LLC., CRC Press, Boca Raton, distributors, 2000.

Wagner, S.A., Clark, M.A., Wesche, D.L. et al., Asphyxial deaths from the recreational use of nitrous oxide, *Journal of Forensic Sciences*, 37(4), 1008–1015, 1991.

Wetli, C.V., Investigations of drug-related deaths. An overview, *American Journal of Forensic Medicine and Pathology*, 5(2), 111–120, 1984.

Wetli, C.V., Mittleman, R.E. and Rao, V.J., *An Atlas of Forensic Pathology*, ASCP Press, Chicago, 1999.

Wetli, C.V., Mittleman, R.E. and Rao, V.J., *Practical Forensic Pathology*, Igaku-Shoin, New York, 1988.

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